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# COSHOCTON - TYPE RUNOFF SAMPLERS

## LABORATORY INVESTIGATIONS

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*By*
*Donald A. Parsons*
*Hydraulic Engineer*

In cooperation with the
St. Anthony Falls Hydraulic Laboratory
and the
Minnesota Agricultural Experiment Station
of the
University of Minnesota

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# COSHOCTON-TYPE RUNOFF SAMPLERS[1]

## Laboratory Investigations

By Donald A. Parsons, formerly hydraulic engineer, Soil Conservation Service[2]

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## INTRODUCTION

### Purpose of Samplers

Runoff samplers are needed by those who are endeavoring to find out how various kinds of land use affect the amounts of runoff and soil erosion. Most of the investigative work is being done by the State Agricultural Experiment Stations, Soil Conservation Service, former Bureau of Plant Industry, Soils, Agricultural Engineering, and Forest Service. The volumes of soil and water lost in the runoff resulting from some storms are so large, even from very small land areas, that trying to catch all of the runoff for the purpose of measurement is impractical. Devices that give a record of the variation in the rate of runoff, and instruments that divide the runoff and store a small portion for subsequent measurement, have been devised and extensively used.

A runoff sampler divides the flow from an experimental area and retains the smaller part of it in a storage tank. Types of measurements of the stored sample made after runoff ceases depend upon the method of runoff measurement that is used. In one of the methods, a supplementary instrument is used to give a record of the rates of flow from which the total volume of runoff can be computed. In this method, the stored field sample obtained from the sampler is itself sampled to provide smaller representative samples for laboratory analysis. Laboratory determination of the soil content per unit volume is then applied to the total runoff amount, as determined by the supplementary instrument, for computing the total soil loss for the runoff period. The volume of the field sample is not measured.

If, on the other hand, the sampler is depended upon to measure the total runoff, the volume of the stored-field sample must be measured. The total runoff is then determined by dividing the volume of the stored-field sample by the known proportion of the runoff flow (sometimes called the aliquote part) the sampler extracts. The soil loss is then computed as described previously. Since the runoff sampler has two functions in this case, and the allowable error in water-runoff measurements is smaller than in soil-loss determinations, the requirements for a satisfactory apparatus are more difficult to meet.

The Geib multislot divisor runoff sampler has been used most extensively by the Soil Conserva-

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[1] Many people contributed to the work upon which this report is based. Many more are now helping with field trials of the apparatus. H. E. Middleton, Assistant Chief of Research, was principally responsible for the continued effort that was required and personally participated in some of the hydraulic tests. L. A. Jones, formerly Chief, Division of Drainage and Water Control, gave aid and advice on general aspects of the work. Orville E. Hays, Project Supervisor, Soil Conservation Experiment Station, La Crosse, Wis., contributed greatly by furnishing the Owen, Wis., version of the original device, by conducting preliminary field trials of experimental samplers, and by his consistently high interest and encouragement during the progress of the work. Among other things his field trials resulted in an increase in vane curvature. This was devised by Pomerene in his early models.

An original Coshocton runoff sampler with curved perforated vanes, flat sampling slot, and inclined axis, as created by W. H. Pomerene in 1944, was furnished by L. L. Harrold, Project Supervisor, North Appalachian Experimental Watershed, Coshocton, Ohio. Field runoff and soil-loss data were also furnished from this project. C. A. Donnelly, Hydraulic Engineer, and Fred W. Blaisdell, Project Supervisor, at the St. Anthony Falls Hydraulic Laboratory assisted in the prosecution of the work in many ways. Sigurd H. Anderson, formerly Hydraulic Engineer, St. Anthony Falls Hydraulic Laboratory, contributed much to the structural features of the devices and to methods of construction. Helpful advice was given by L. G. Straub, Director, St. Anthony Falls Hydraulic Laboratory, who also was first to explain the basic principle of operation of the samplers. The skillful work of J. Baur, C. Anderson, R. Murdock, and others at the laboratory was indispensable. The writer is indebted to all these and many others.

[2] The work upon which this report is based was a cooperative undertaking of the Soil Conservation Service of the U. S. Department of Agriculture with the St. Anthony Falls Hydraulic Laboratory and the Minnesota Agricultural Experiment Station of the University of Minnesota.

The personnel and projects mentioned herein have been transferred to Agricultural Research Service of the U. S. Department of Agriculture since this report was prepared.

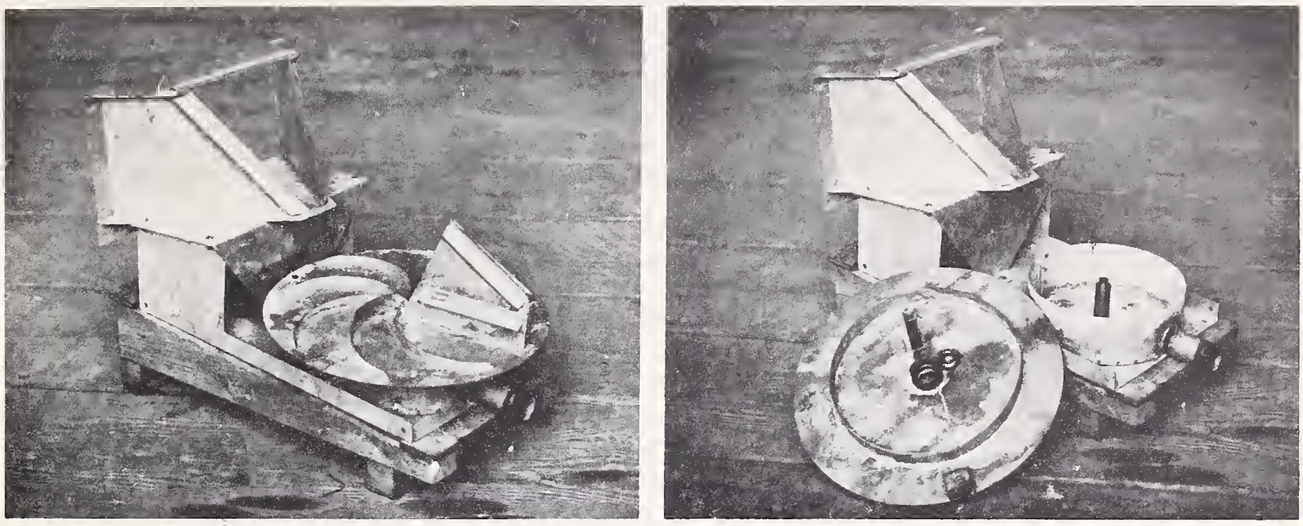

Figure 1.--Model N-1 runoff sampler unit.

tion Service. Many hydraulic tests were made on this device by the Soil Conservation Service at the Hydraulic Laboratory of the National Bureau of Standards prior to its adoption for general use. When properly constructed and installed, this device is capable of giving very good results. Even though we have a device or devices capable of giving good results, the incentive for the development of other devices arises from the fact that the total costs of making soil-loss and water-runoff measurements are large and thus should be reduced if possible.

## The Coshocton-Type Sampler

The Coshocton-Type Sampler was first developed by W. H. Pomerene of the North Appalachian Experimental Watershed, Coshocton, Ohio, formerly with the Soil Conservation Service. Its form is illustrated by Plan File No. PSS-1, dated October 9, 1947, of the Coshocton project. Forms of this device are still being used for field measurements near Coshocton,[3] Ohio, and Owen, Wis. They are used in conjunction with rate-measuring flumes equipped with water-level recorders and, therefore, are not being depended upon to measure the total runoff.

Operation of the Coshocton-Type Runoff Sampler is simple. The discharge from the measuring flume falls upon a water wheel, whose axis is inclined slightly from vertical. A sampling head, with a narrow opening (hereafter called the slot) along its top, is mounted on the wheel. With each revolution of the wheel, the slot cuts across the jet from the flume and extracts a small portion of the flow. The extracted portion, or sample, falls through the inside of the sampling head, through the wheelplate, and into a collecting pan beneath the wheel. From there, the sample is conducted through a suitable closed conduit to a sample-storage tank.

Samplers in use at Owen differ a little in design from those at Coshocton. One sampler from each of the two research projects was tested under controlled flow conditions at the St. Anthony Falls Hydraulic Laboratory of the University of Minnesota. This was a preliminary step to the possible use of this type of instrument at other locations throughout the country. Curiosity as to the reasons for the differences in behavior of the two samplers, and the rather wide variation exhibited by both in the proportion extracted as the flow was changed, prompted modifications in construction and additional tests.

The first modification consisted of raising the sampling slot to reduce the effect of the splashing that resulted from the impact of the jet on the wheel. The results of this change were encouraging and raised the hope that the devices could be designed to measure satisfactorily both the soil loss and water runoff. The laboratory work was continued and resulted in 65 series of tests. About 1,300 individual tests were made. The detailed results of the laboratory work were given in a separate report.[4]

Standardized designs have been prepared for samplers with diameters of 1 foot and 2 feet, designated as Models N-1 and N-2, respectively. Photographs of a Model N-1 sampler are shown in figure 1. The results of steady flow-calibration tests with several samplers of both sizes are given in figures 2 and 3. Figure 4 shows how

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[3] Harrold, L. L. Soil loss as determined by watershed measurements. Agr. Engin., 30: 137-140. 1949.

[4] Parsons, D. A. Calibration and development tests, Coshocton-Type Runoff Samplers. August 1951. [Typewritten.]

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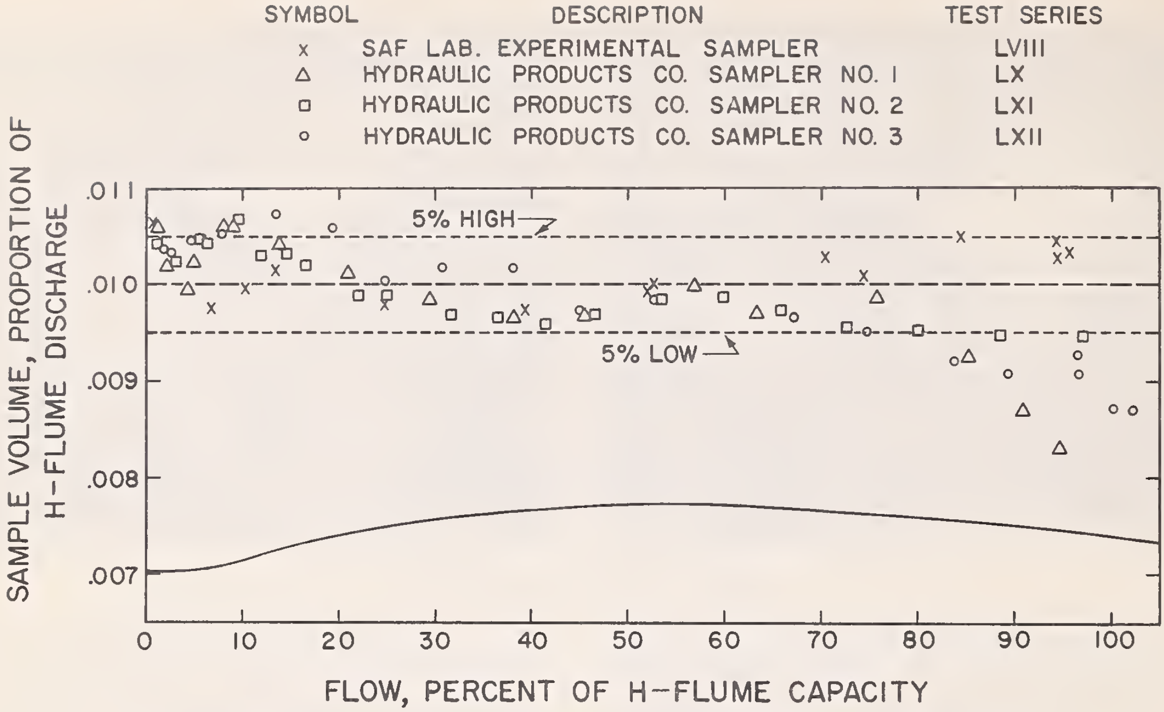

Figure 2.--Calibration tests, Model (N-1) Coshocton-Type Runoff Samplers (1-foot diameter wheels with 6-inch H-flumes).

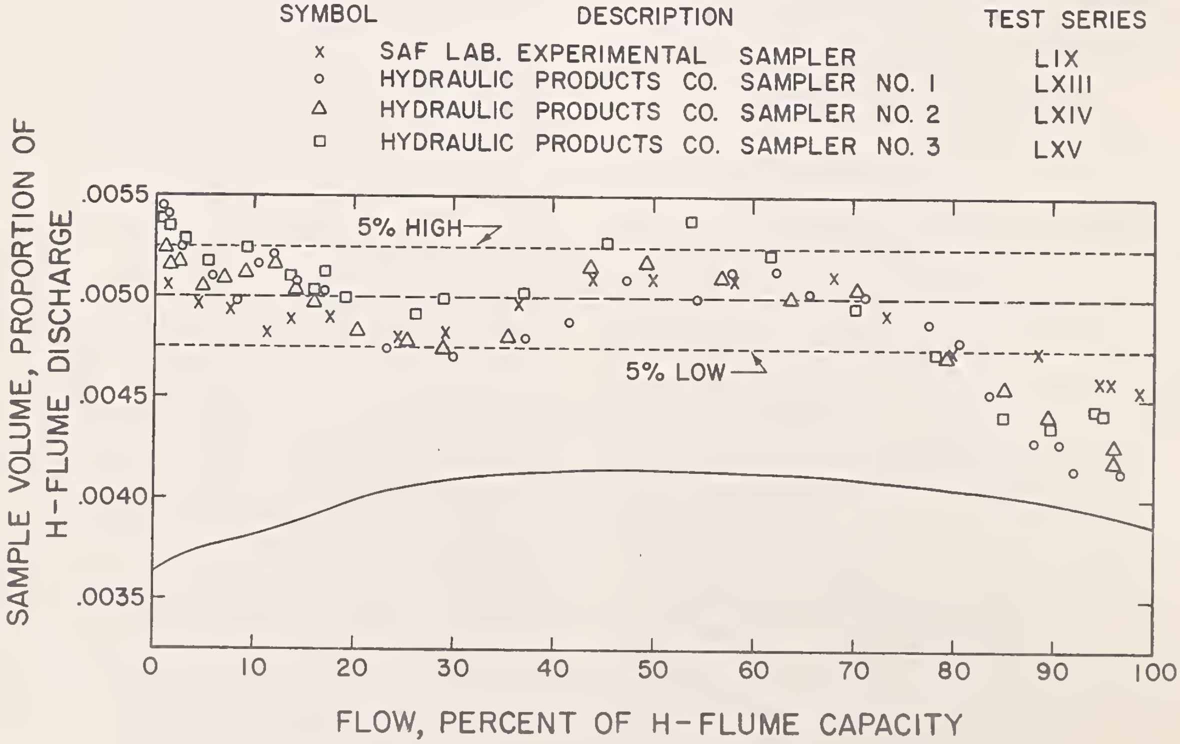

Figure 3.--Calibration tests, Model (N-2) Coshocton-Type Runoff Samplers (2-foot diameter wheels with 1-foot H-flumes).

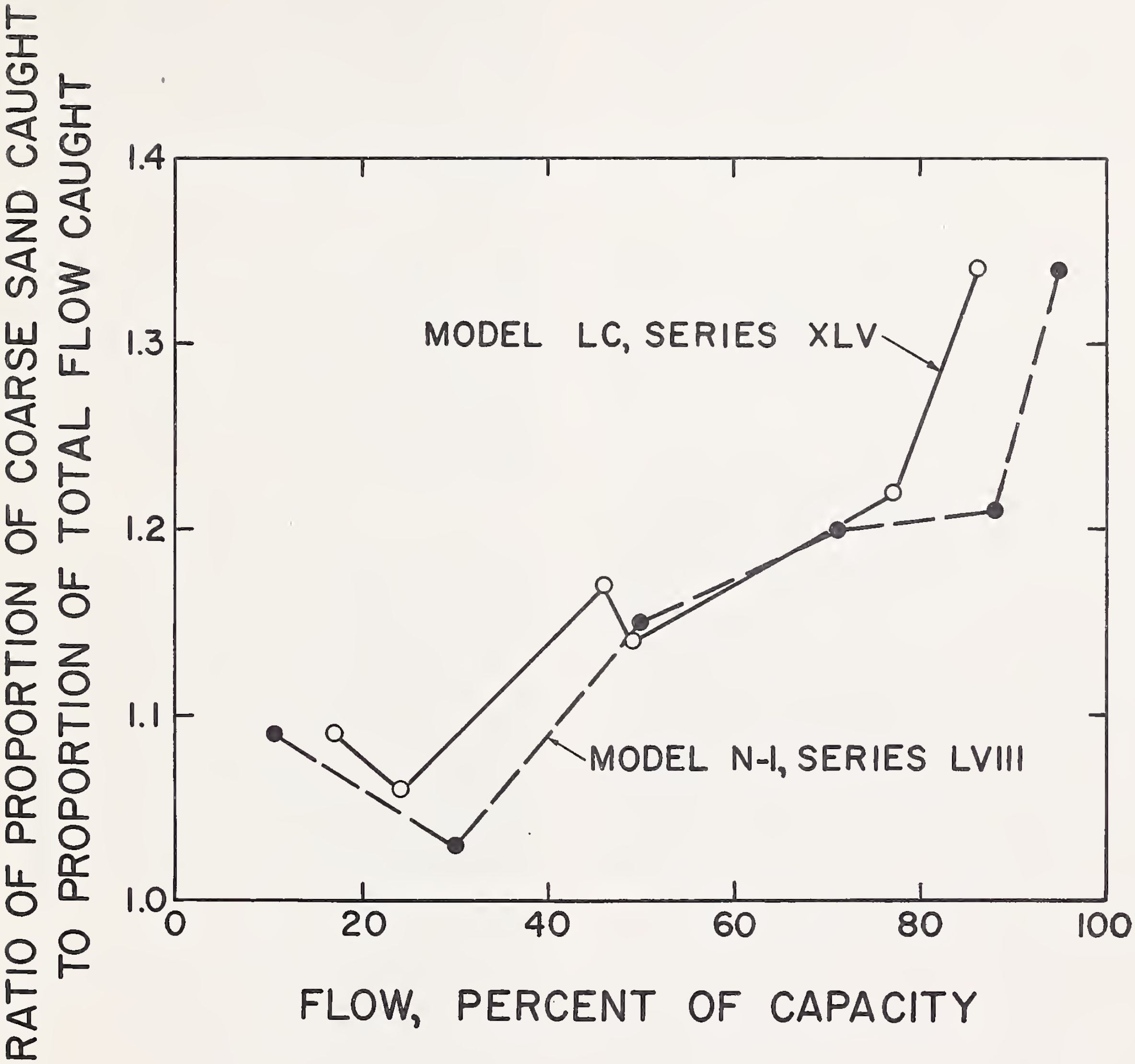

Figure 4. --Ratio of soil concentration of sample to that of runoff.

coarse sand (0.59 mm. to 0.83 mm. diameter), introduced at floor level in the measuring flume, is sampled by the 1-foot diameter sampler.

## SAMPLER EVALUATION

### Characteristics of a Satisfactory Sampler

While developing a sampler, or judging its satisfactoriness for general use, it is pertinent to explore the characteristics that are important to acceptable operation. A brief discussion of these characteristics follows:

Capacity.--High capacity is desirable. It permits use of the instrument over a large range of site and runoff conditions, thereby reducing the number of types and sizes of samplers required to make the needed measurements. A capacity of 10 inches per hour, which is about 10 cubic feet per second per acre of experimental area, is about right for agricultural areas in the United States when conditions on the plot are extremely favorable for runoff production. Less than half of this capacity is needed for some combinations of plot characteristics.

Size of sample.--A small sample is preferred. Storage capacity of the sampler installation should be something less than 20 cubic feet, even for installations on the larger areas. Reasons for limiting the size of the storage tanks are the original cost, the cost of installation, and the fact that the stored sample must in turn be sampled for laboratory purposes. Large volumes are more difficult to sample accurately than small volumes. Since the volume of runoff from the maximum storm may be as much as 20,000 to 30,000 cubic feet per acre of experimental area, the percentage of the total flow that the sampler extracts must be small even from small plots.

Accuracy.--The degree of accuracy of the sampler must be consistent with the objectives of the measurements. Accuracy in the determination of soil loss and water runoff depends not only upon the sampler but also upon the adequacy of the plot borders and collecting trough, the general care by the operators, the skill in resampling the storage tank, and the precision of operations in the laboratory. The sampler is one unit in a process, and should be held accountable insofar as its design affects the number of operations, chances for error, or the magnitude of the error in an operation. Because there are several sources of error, the maximum sampler error should be less than the total error permissible in attainment of the objective of the measurements.

Reliability.--Runoff samplers must be capable of dependable, automatic operation for continuous periods of at least 2 days. They are often placed in remote positions and in such numbers that servicing, following a period of runoff, cannot be accomplished for a considerable length of time. Whereas many of the schemes proposed for sampling runoff will easily meet the accuracy requirements for short periods of clear-water flows, few will meet the reliability requirement under usual field conditions. Trash--such as leaves, stems, and roots of plants carried by the runoff water--is probably the greatest source of difficulty. Many other factors are also involved, including sedimentation in the apparatus, wind, insects, and corrosion.

Headroom.--A low headroom requirement is essential for a generally satisfactory sampler. All samplers require a drop in the water-surface elevation as the runoff passes through the apparatus. The minimum headroom requirement of a sampler becomes an all important matter for installations on gentle slopes and in places where high tailwater may occur in the outlet channel during heavy runoff.

Costs.--The design and construction of a sampler should be such that the average cost of making a satisfactory measurement of soil loss and water runoff is as small as possible. Soil and water-conservation research requires a large number of runoff measurements, owing to the wide variations in climate, topography, soils, soil treatments, tillage methods, and plants. The rate at which fact finding progresses is necessarily dependent upon the number of soil-loss and water-runoff measurements that can be made with available funds.

### Accuracy Goals

Deviations from true values in measurements of soil loss and water runoff occur with individual judgment; yet, an objective approach to the evaluation of samplers requires a specific statement of the accuracy goals. What they shall be depends upon the use that is to be made of the data. The notions of the writer in this regard are:

Maximum allowable error in soil loss determination: 25 percent or 100 pounds per acre, whichever is the larger;

Maximum allowable error in water-runoff determination for use in comparative studies: 10 percent or 0.04 inch, whichever is the larger;

Maximum allowable error in water-runoff determination for use in an intensive accounting of all rainfall disposition: 5 percent or 0.02 inch, whichever is the larger.

These estimates apply to individual runoff periods. The probable errors would be less. The probable relative error of the sum of the amounts for several runoff periods would be still less. The permissible error of the sampling device for a single runoff period would be less than the allowable error for the overall measurement.

### Other Factors in Evaluation

Other factors are involved in the determination of the sampler error. And, to be correct, two types of error should be recognized. At a particular rate of water-runoff through the apparatus, the proportion of the volume extracted by the sampler will differ somewhat from the proportion that was intended. Also, the concentration of transported material in the sample will differ somewhat from the concentration of transported material in the total flow through the apparatus.

Two reasons can be given for the difference between the concentration of transported material in the sample and in the total flow at a given rate of discharge. First, the inertia of large, heavy particles will cause their paths to differ from that of the fluid if the flow lines are curved as the runoff enters the sampling slot. Secondly, it is to be expected that the sampler will not extract exactly the same percentage from each element of the cross section of the runoff jet. Then, if the concentration of soil in the runoff differs over the cross section, because of the large size of the transported particles and a large difference in density between the fluid and the particles, the percentage of transported material in the sample will differ from that in the total flow.

The data in figure 4 are an illustration of the relative variation in the case of coarse sand being transported within a small element of the cross section. It is to be expected that finer, or less dense, material distributed more uniformly in the runoff would be divided more nearly as the liquid is divided.

Differences between the intended and actual proportions of the runoff caught by the sampler differ with the different rates of flow. The data of figures 2 and 3 illustrate results that are obtained in the laboratory-calibration tests at steady flows. The error pattern, or variation of error with rate of flow, would have been identical for each device of a kind if flow conditions and all details of construction had been exactly alike.

Unfortunately, laboratory data obtained at steady flows do not show what the sampler error will be for some random period of runoff. The flow ranges during a runoff period from zero to a maximum value and back to zero. The error for the runoff period will be an average for the range in flow and will be less than the maximum steady-flow error within the range. It is possible, therefore, for an instrument to be satisfactory even though the steady-flow error at some period of flow exceeds the allowable error.

A calculation, from the steady-flow calibration, of the sampler error in measuring the volume of runoff for a runoff period requires a knowledge of the shape of the runoff hydrograph. Also, since the soil concentration in the runoff usually differs throughout the runoff period, an error variation in the volume extracted by the sampler introduces an error in the average soil concentration in the sample. Thus, the variation in the soil concentration in the runoff throughout the runoff period must also be known to make a calculation of the error in the soil concentration in the sample.

It is obviously impossible to foretell the exact shapes of the hydrographs and variations in the concentration of soil in the flow during runoff periods to come. An approximation of future conditions, however, may suffice for making a conclusion regarding the satisfactoriness of a sampler. For example, it could be assumed as an approximation that all hydrographs can be sufficiently well represented by triangles. Then, by geometry and algebra, the proportion of the total runoff that occurs within any rate interval, in terms of the maximum rate, can be determined easily. Thus, for triangularly shaped hydrographs half the runoff occurs at rates greater than 81 percent of the maximum and half occurs at lower rates.

An alternative to this procedure, and one that also provides information on the expected errors in concentrations of soil in the runoff, is to use actual measurements of hydrographs and soil concentrations and assume that, for this purpose, they are a sufficiently close approximation of what is to come in the future.

## Examples of Evaluation

Figure 5 is a rough presentation of a few data furnished by the Coshocton station. It is used to represent runoff in general in an illustration of the determination of the magnitude of errors. The runoff rates and soil concentrations are shown as proportions of the maximum value. The time scale is arbitrary but is consistent for the curves shown. The soil-flow curve is obtained by multiplying concurrent values of $\frac{C}{C_{\max}}$ by $\frac{Q}{Q_{\max}}$. The total area under the soil-flow curve divided by that under the runoff curve gives the average soil concentration in the whole runoff. For the conditions shown $\frac{\bar{C}}{C_{\max}} = 0.76$; that is, the average concentration is equal to 0.76 times the maximum concentration.

The proportions of the total runoff and the total soil loss occurring in each of 10 flow ranges are shown in table 1.

TABLE 1.--Runoff and soil-loss proportions by flow ranges for the runoff conditions of figure 5

| Runoff range $Q/Q_{\max}$ | Proportions of total | |
|---|---|---|
| | Runoff | Soil loss |
| 0 - .1 | 0.046 | 0.020 |
| .1 - .2 | .058 | .040 |
| .2 - .3 | .058 | .048 |
| .3 - .4 | .064 | .058 |
| .4 - .5 | .069 | .066 |
| .5 - .6 | .086 | .086 |
| .6 - .7 | .099 | .104 |
| .7 - .8 | .132 | .138 |
| .8 - .9 | .147 | .157 |
| .9 - 1.0 | .241 | .281 |

Selecting the calibration curve for Model A (Series I) (fig. 6) as an extreme example of variation, the appropriate sampler ratio for each of the 10 flow ranges is multiplied by the corresponding proportions. The sums of these products represent the relative size and soil content

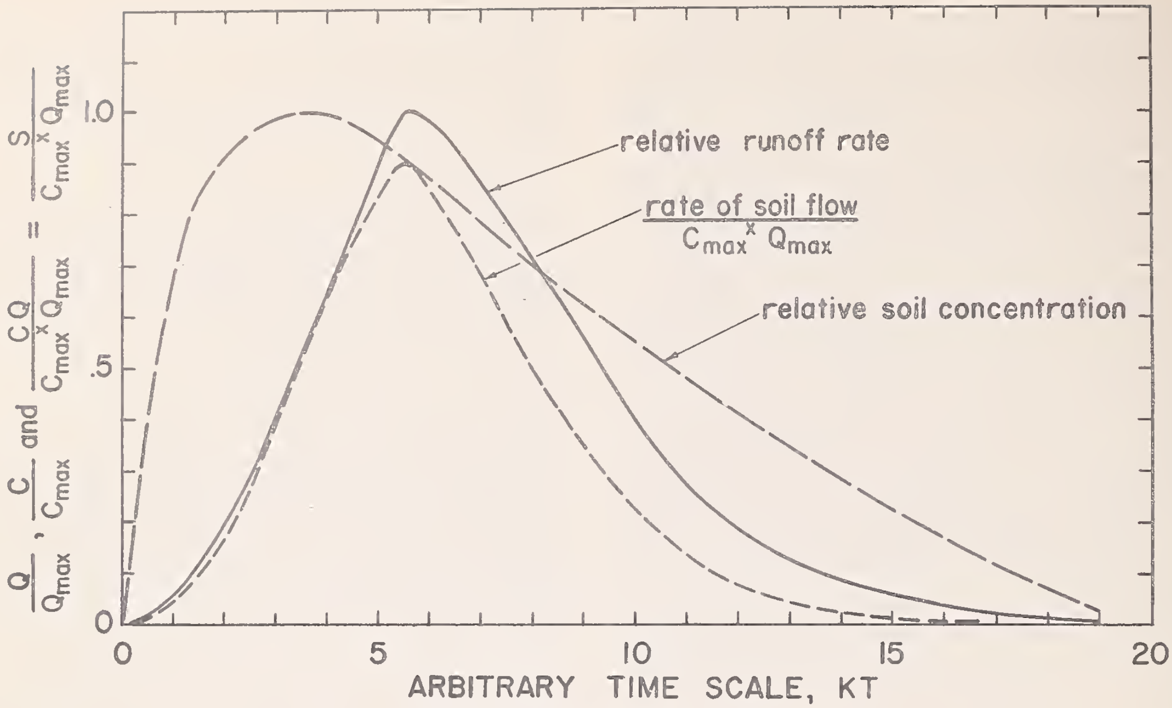

Figure 5. --Generalized runoff.

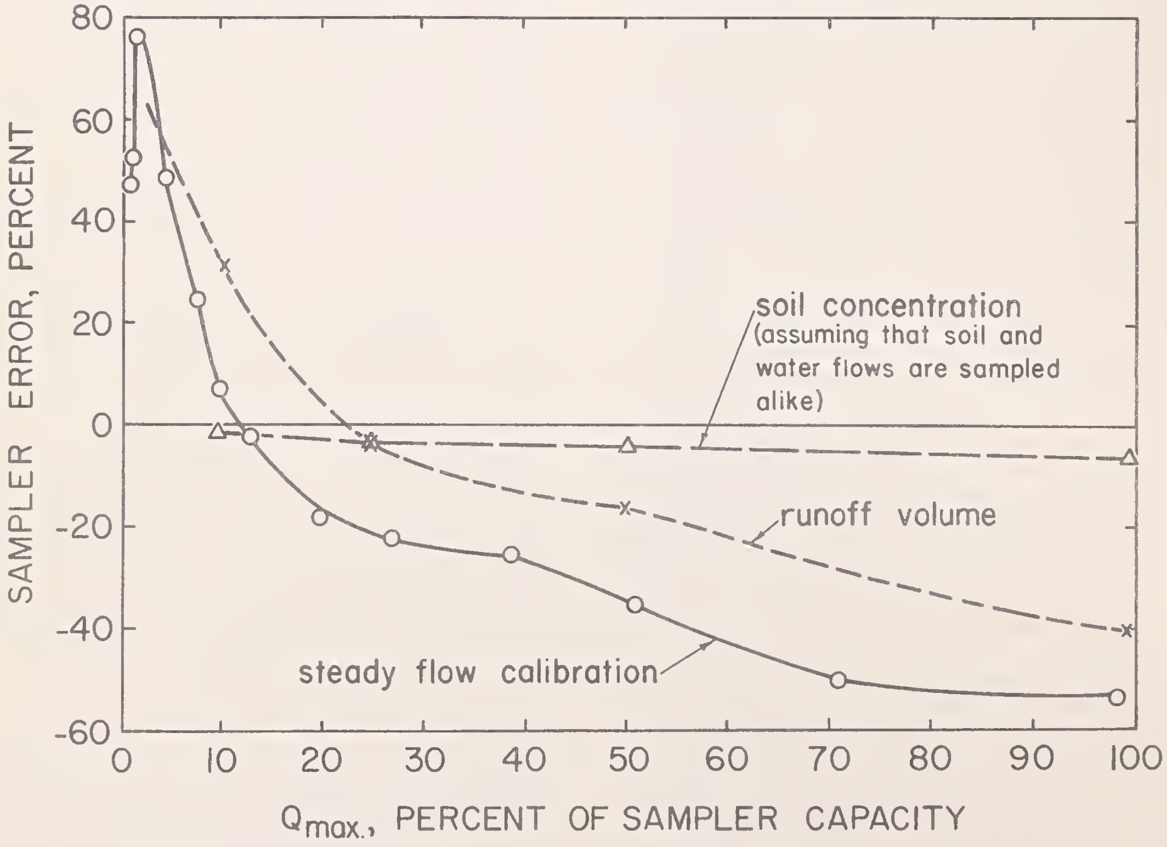

Figure 6. --Illustration of sampler errors (Model A) for runoff as shown in figure 5.

of a sample that would be obtained during a runoff period. This may be done for several values of maximum flow within the capacity of the sampler. The difference between the size of the computed sample volume and the intended sample indicates the magnitude of the error in runoff-volume determination, if the sampler had been used for this purpose. The ratio of the soil-loss sum to the runoff sum indicates the extent of the deviation in the soil concentration in the runoff extracted by the sampler from that in the total runoff. Figure 6 shows the results of these calculations. It was assumed that the sampler would divide the soil flow and water runoff in exactly the same manner.

Although this example is based upon limited soil loss and runoff data, it is believed to indicate quite clearly that a satisfactory sampler for soil-loss determination may have a large range in the value of the ratio of sampler catch to total flow, if it is used with a good, independent means of determining the total runoff. Even though the maximum value of the ratio of sampler catch to total flow was nearly four times greater than the minimum, the resultant error in sampling the soil concentration in the runoff due to this variation was well below the allowable error.

The results of similar calculations for the Model N-1 sampler are shown in figure 7. Such computations should suffice in error evaluation, except for borderline cases.

## OPERATING CHARACTERISTICS OF THE COSHOCTON SAMPLER

### Basic Principle

The basic idea of the Coshocton Runoff Sampler is as follows. Given a jet of liquid with flow $Q$, width $x$, thickness $y$, and velocity $v$, as shown in figure 8, a slot with length greater than $y$, and with width $w$, is passed through the jet at a speed $s$, in the direction of $x$. The flow into the slot is

$$Q = wyv$$

The volume of liquid extracted by the slot as it passes through the jet is $qt$, where $t$ is equal to $x/s$. In the case of a radial slot mounted on a wheel $s$ is $2\pi rn$. The volume extracted for one pass through the jet is then $\frac{wyvx}{2\pi rn}$. The volume extracted in unit time, which would be the amount caught in $n$ passes, is

$$\bar{q} = \frac{wyvx}{2\pi r} = \frac{wQ}{2\pi r}.$$

The ratio of the mean flow from the slot to the total flow of the jet is, therefore, $k = \frac{w}{2\pi r}$, which in words is the ratio of the slot width to the circumference at any radius. The sampler ratio (or aliquot) $k$ is, therefore, independent of the average rate of turning of the wheel.

The foregoing is a considerable simplification of the actual operation of the Coshocton Runoff Sampler.

### Actual Operation

Some of the differences between the actual conditions and the expressed and tacit assumptions are:

(1) The total cross-sectional area of the jet is not completely crossed by the slot at the highest discharges;

(2) The velocity of the slot is variable in both time and direction;

(3) The solid boundaries of the sampling head and wheel cause fluid forces and consequent deflections of the liquid that were not considered;

(4) Because of the splashing that results from the impact of the jet on the sampler, some of the liquid at some flows is sampled twice.

A restatement of the factors that influence the proportion of the total flow extracted by the sampler should include the following:

(1) The ratio of slot width to circumference;
(2) The uniformity of rotation throughout a turning cycle, influenced by:
    (a) The size and shape of the sampling head,
    (b) The size and number of the turning vanes,
    (c) The speed and direction of the runoff at impact with the wheel,
    (d) The position of the sampler relative to the jet.
    (e) The moment of inertia of the wheel,
    (f) The tilt of the wheel, and
    (g) The balance of the wheel.
(3) The proportion of the jet sampled;
(4) The amount of splashing into the slot;
(5) The thickness of the edges of the slot;
(6) The mean speed of the slot as it passes through the jet, in turn determined by most of the factors under (2);
(7) The speed and direction of the jet being sampled.

The data in figures 2, 3, 4, and 7 represent the end products of the complicated behavior of these devices. Some of the details of operation are given in a subsequent section in which various construction features are described.

Observations made during the calibration of the several models that were tested may be of interest. Changes in design that caused an increase in the rate of turning at a given discharge usually decreased the proportion of the flow extracted by the sampler. The average rate of turning increases with increasing discharge up to about midcapacity. The average turning speed decreases with increasing discharge beyond about two-thirds of capacity. The turning speed is quite nonuniform at the high discharges. The average rate of turning differs inversely as the square root of the sampler diameter, in accordance with similarity principles.

## NOTES ON SAMPLER-UNIT DESIGN

### The Unit

Models N-1 and N-2 of the Coshocton Runoff Sampler are constructed to form single units

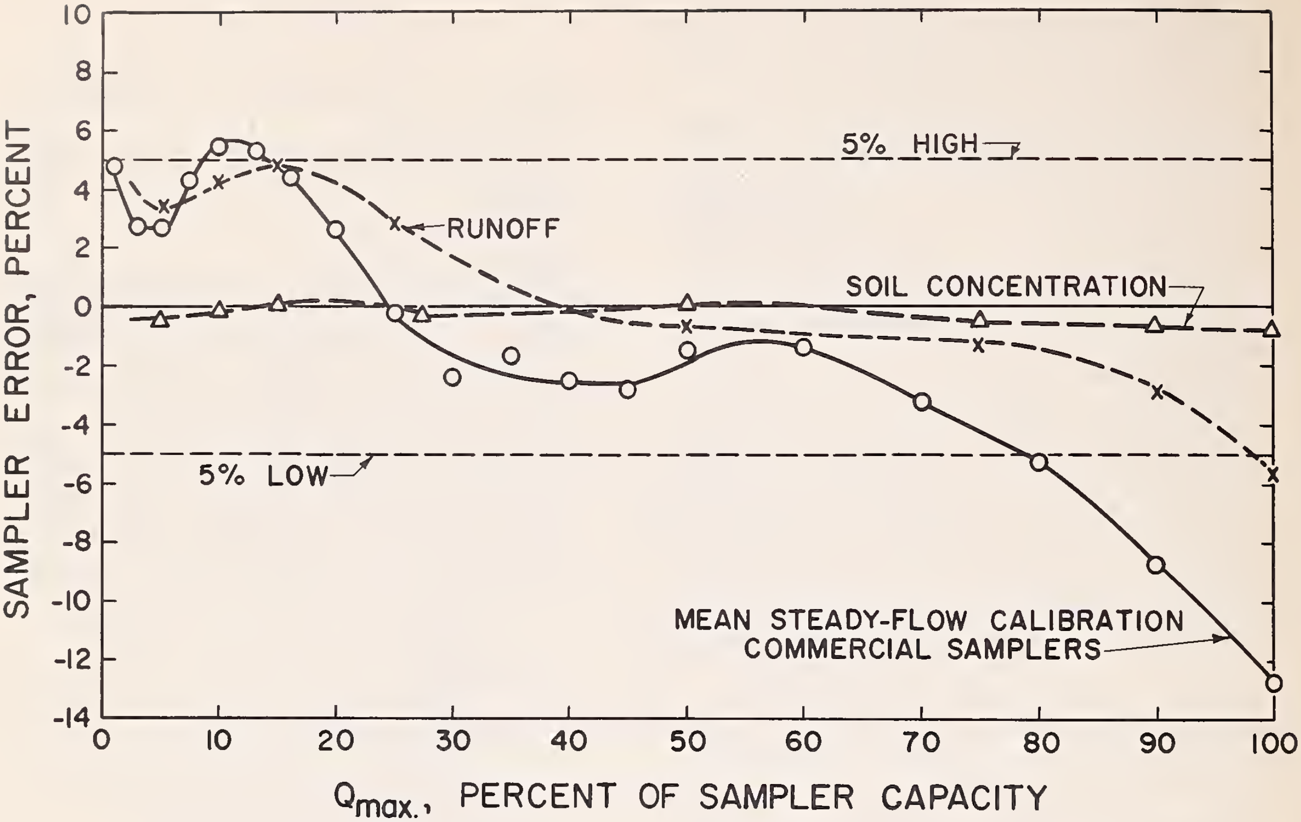

Figure 7.--Illustration of sampler errors (Model N-1) for runoff as shown in figure 5.

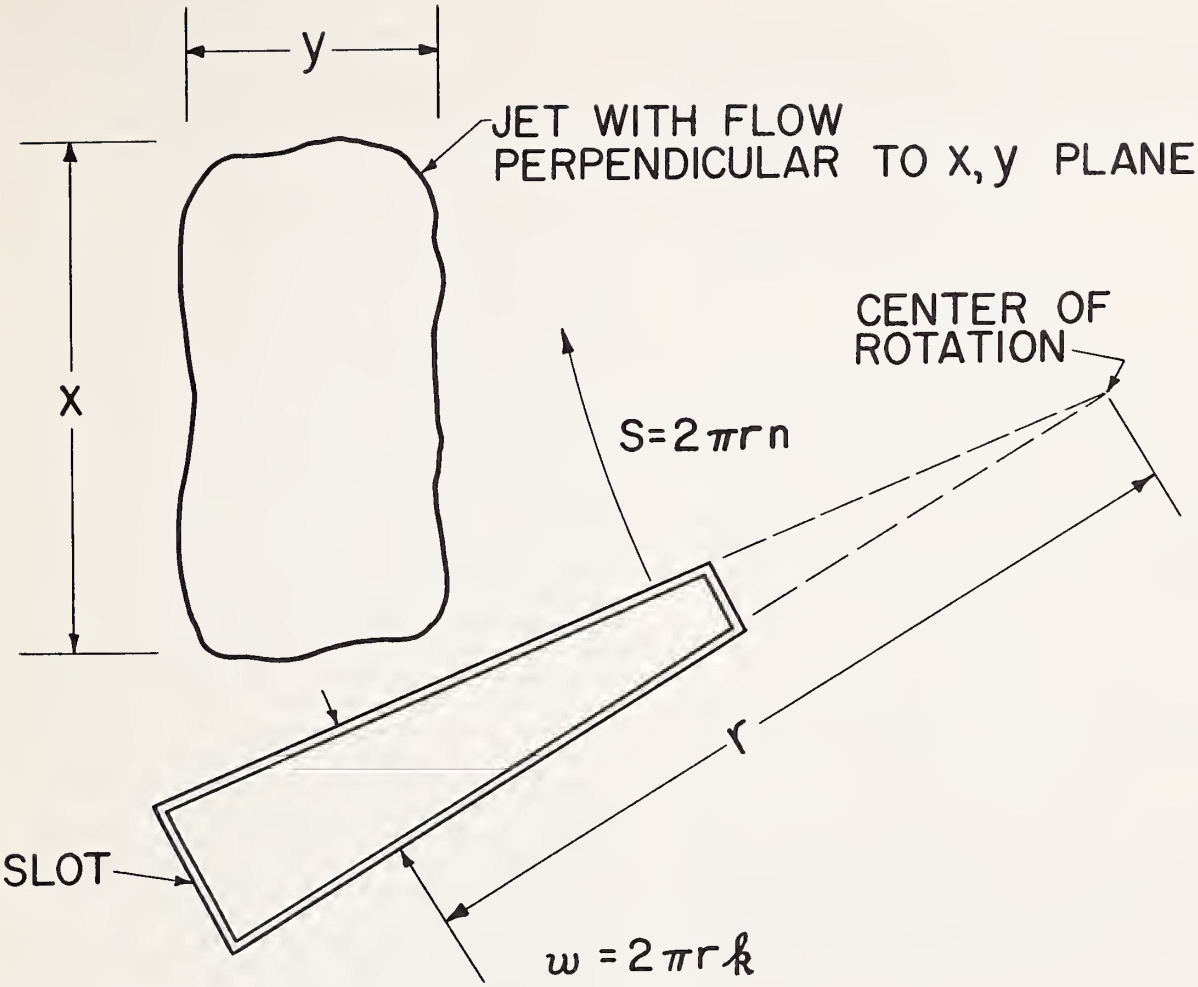

Figure 8. --Simple elements of the operation of the Coshocton-Type Runoff Sampler.

consisting of the sampler, a type H-flume, and a supporting frame. The flume is provided to give a standardized approach flow to the sampler and to provide the means, if desired, to measure the peak-runoff rates. The supporting frame insures proper orientation of the sampler and flume and facilitates field installation of the device. The H-flume capacity is arbitrarily considered to be the capacity of the unit. The flume depth is equal to half the nominal diameter of the sampling wheel.

## Counterweight

A counterweight is placed opposite the sampling head in order to balance the wheel. If the wheel is out of balance, trickle flows either will not be sampled or will be sampled at a nonuniform rate of turning. If, however, it is considered that there is too much chance for the slot to stop within the flume discharge at extremely small flows, a slight out-of-balance so that the slot will stop on the right side, looking downstream rather than at the bottom, is preferable.

## Bearing

A bearing with low friction is essential. It is to be expected that new bearings will be needed occasionally.

## Sampling Head

The slot is raised away from the wheelplate to reduce splashing in. The splash deflector serves the same purpose and is needed over a small range of flows at about one-seventh capacity. The inside width of the slot is determined by the equation

$$w = \frac{2\pi r P\ q/Q}{1 + 1.6T}$$

where: $r$ = radial distance from center of wheel;

$T$ = thickness of metal at the slot edge, inches;

$q/Q$ = proportion desired to be extracted by the sampler (0.01) for the N-1 drawing and 0.005 for the N-2 drawing);

$P$ = a modifying coefficient that was changed from unity in value for several experimental models to increase the proportion of the runoff extracted and decrease that of the transported bed material during the high discharges. The value of $P$ for the slot shown in the N-1 drawing is $P = 0.93$ at $r = 6$ inches and $P = 1.00$ at $r = 2$ inches. For Model N-2, $P = 1.05$ at $r = 12$ inches and $P = 1.35$ at $r = 4$ inches. Intermediate slot widths are interpolated. It probably would be best to keep $P$ unity for samplers to be used in any other way than is indicated on the general plan.

## Weight and Mass Distribution

Since at high flows the moment of force causing rotation differs considerably throughout a turning cycle, the moment of inertia of the wheel about its center must be great enough to maintain motion during periods of low or adverse turning moment. The necessary and sufficient moment of inertia of the N-1 sampler wheel about its center is 0.027 slug-ft$^2$. Similarity of operation of different size samplers requires that the ratio of the moments of inertia of two samplers be equal to the fifth power of the ratio of their linear dimensions. Thus, the N-2 sampler, which is twice as large as the N-1 model, must have a moment of inertia $2^5 = 32$ times greater, or 0.87 slug-ft$^2$. Weight becomes an increasingly important matter in the cost and handling of the equipment as the sampler size increases. Extra mass to meet the moment of inertia requirement is therefore placed near the periphery of the larger sampler where its effectiveness in rotation is greatest.

## Turning Vanes

The design of the turning vanes reflects the fact that the principle of operation differs for high and low flows. Turning at high flows is a result of fluid forces on the vanes resulting from the change in speed and direction of the jet at impact. The turning forces at trickle flows are a result of the acceleration due to gravity acting upon the liquid caught behind the vanes.

Smooth, dependable action at very small flows requires many vanes. Only a small height is required. This is fortunate, since small height is desirable at the higher flows to obtain relatively low rates of turning and low slot speeds. Additional height at the inner end of the second vane, clockwise from the sampling head, is for the purpose of reducing a hump in the calibration curve at about one-seventh capacity.

The small hole near the inner end of each vane is provided as an aid to starting the wheel for trickle flows. The leakage through these holes distributes the water over the wheel in a manner to give a greater starting torque. The curvature of the vanes is also a factor in this regard since it affects the amount of water that can be held above them.

## Position

The center of the sampler wheel is offset from the approach flume centerline to avoid stalling of the sampler at both high and low flows. The offset is kept small for two reasons: (1) A smaller portion of the jet area will be unsampled at the highest flows, and (2) average turning rates are kept lower at intermediate and high discharges.

### Tilt of the Wheel

The tilt of the wheel has little, if any, effect upon the proportion of the runoff extracted by the sampler if the wheel is balanced. A small tilt reduces the required headroom for operation.

## NOTES ON CONSTRUCTION

Plans for construction of the Models N-1 and N-2 Runoff Sampler units are shown as figures 9 and 10, respectively.

Although sheet metal is used extensively in the construction of these devices, the precision in fabrication that is required is much greater than is generally associated with sheet-metal work. The pan and its outlet connection, the surface of the wheelplate, and the joints of the sampling head must be absolutely watertight. It is conceivable that a leak could be so small that its effect would actually be negligible but knowledge of the existence of even a very small leak destroys confidence in the validity of the measurements.

It is usual in sheet-metal fabrication to use a considerable amount of heat in making soldered joints. This contributes to good joints and speeds construction. But it has been found in building the samplers that, to minimize warping of the metal surfaces, the heat must be limited to that which is required to obtain good soldered joints. This applies to the soldering work on the wheelplate, the sampling head, and the outlet edge of the H-flume. It has also been found helpful first to spot-solder the vanes to the wheelplate and the stiffeners to the sampling head and the flume outlet. The clamps used to hold the stiffeners in place while the soldering is being done should not be too tight nor put in places where tightening of the clamps would cause stresses in the metal, which in turn would produce undesired deflections after removal of the clamps.

Correct widths of the slot are more readily obtained by the use of two or more micrometered spacers or by a continuous plug of the correct variable width. Slot widths may be conveniently checked at measured distances along the slot with a taper gage similar to Starrett No. 269A.

Check measurements of the lower outlet width of the H-flume are facilitated by the use of a shop-made taper gage. This instrument is readily made by using an outside micrometer caliper to graduate a tapered piece of metal. Since it is almost impossible for several reasons to make a good measurement of the flume-outlet width at floor elevation, it is best to make one or more measurements of width at certain known elevations above floor level. The effective width of the outlet at floor level is the difference between the width at a higher elevation and the distance above the floor that the measurement was taken. The shop-made taper gage may be held at a fixed elevation by placing it on a small plate of known thickness, resting upon the flume floor near the outlet. It is essential to clean the flume floor beneath the plate of any excess solder or other materials.

The most satisfactory method that has been found to obtain the proper alinement of the H-flume axis with the sampler wheel center is by use of a device shown in figure 11. Anyone wishing to construct or inspect many sampler units will need this auxiliary instrument.

## INSTALLATION

### Size of Sampler and Storage Tank

The area of the experimental plot should depend upon the nature of the experiment, but it is often limited by the availability of land of uniform qualities. Instances also arise when the plot area is restricted because of the cost or unavailability of suitable measuring equipment. The data of table 2 are given for use in the preliminary planning.

The relation between plot area and maximum runoff rate that will occur is largely unknown. In fact, its determination may be one of the objectives of the experiment. The same is also true in respect to the maximum amount of runoff that will occur between times of servicing the equipment. Yet, some sort of a guess about these things must be made in order to select a sampler and storage tank of a capacity compatible with conditions. The development of procedures for making these estimates is too lengthy for this report. A method credited to Howard L. Cook by Hamilton and Jepson[5] is suggested for use in determining per-acre runoff rates. The 50-year rate should be used. The area of the plot times the per-acre rate gives the required sampler capacity. It is further suggested that the samplers be considered to have 80 percent of their rated capacity shown in table 2, and that prime consideration be given to the plot conditions most favorable for runoff that may exist during the installation period.

The required size of the storage tank may be estimated by considering the size of the plot, the expected maximum amount of rainfall that will occur in 2 days, and the probable capacity of the soil to take water during the 2-day period of rainfall. For example, the 2-day rainfall to be expected to be exceeded once in 50 years in the eastern United States, according to the Miami Conservancy District[6] ranges from about 5 inches in the extreme north to about 12 inches in the extreme south. This is the same as to say that the chances are about 1 in 10 that these amounts will be exceeded within 8 years, which seems to be a reasonable gamble to take on this feature of apparatus design. Then, as a further example, if the design rainfall at a central location is 8 inches and the soil is estimated to take 2 inches of this rain, the runoff is estimated to be 6 inches. The required volume of the storage

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[5] Hamilton, C. L., and Jepson, H. G. Stock water developments: wells, springs, and ponds. U. S. Dept. of Agr. Farmer's Bul. 1859. 1940.

[6] Miami Conservancy District. Storm rainfall of Eastern United States. Technical Reports, Part V. 1917.

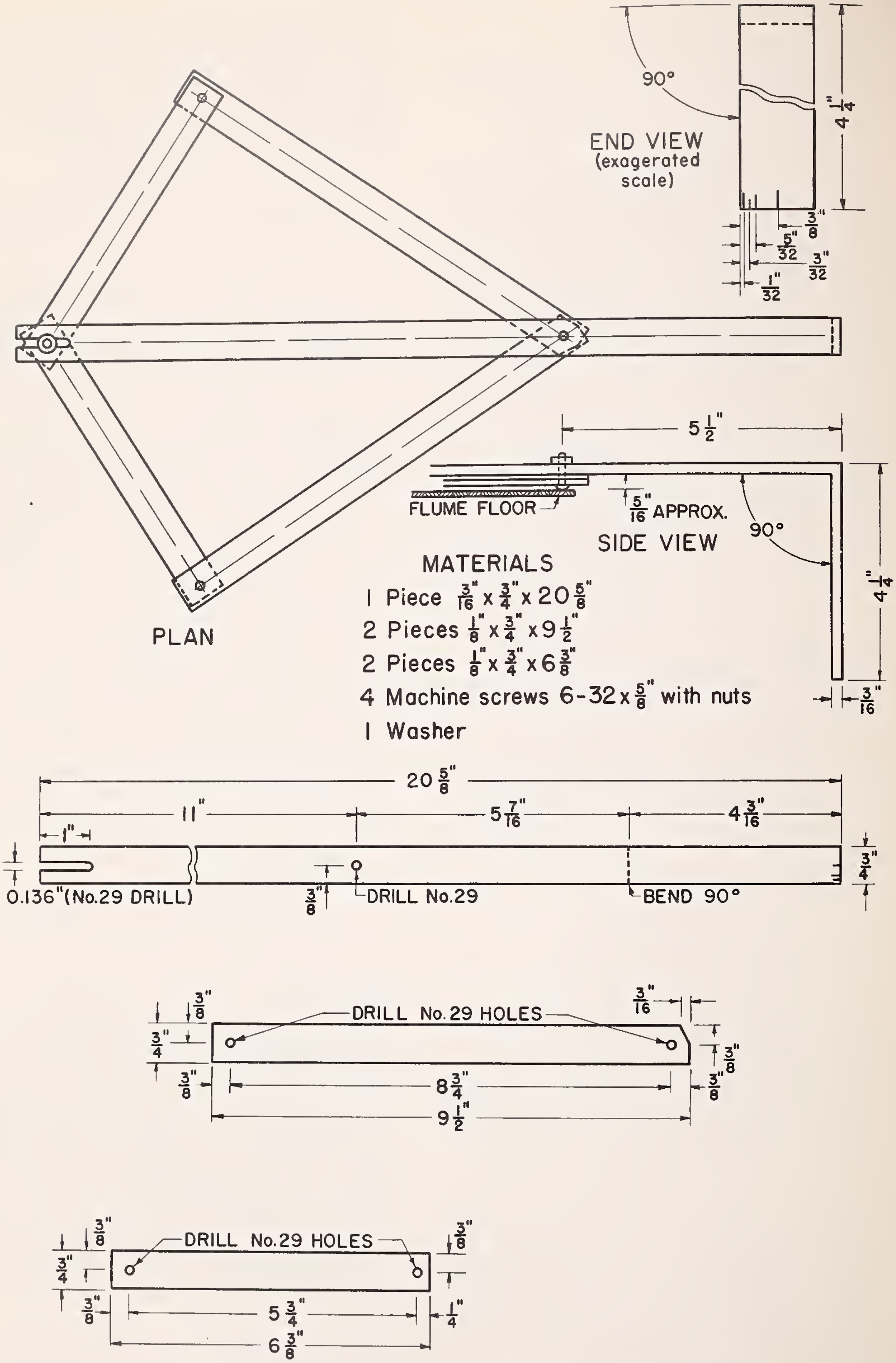
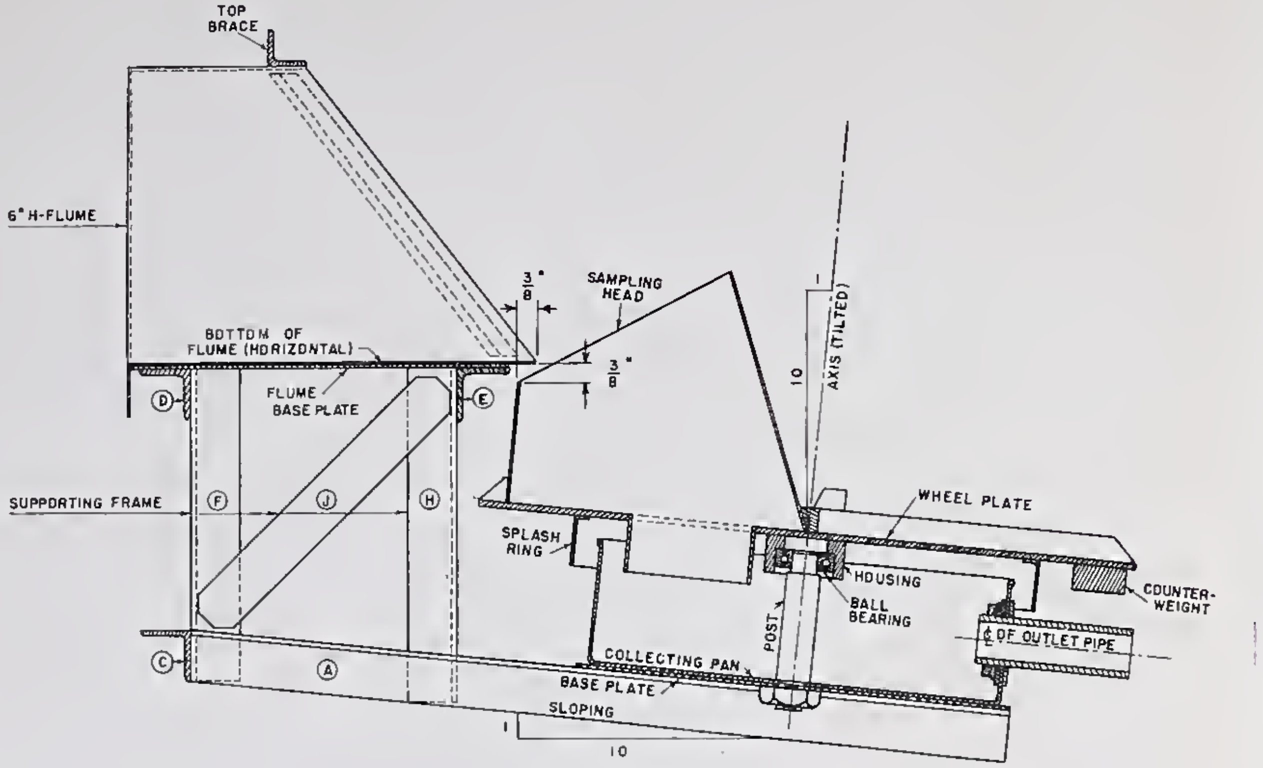
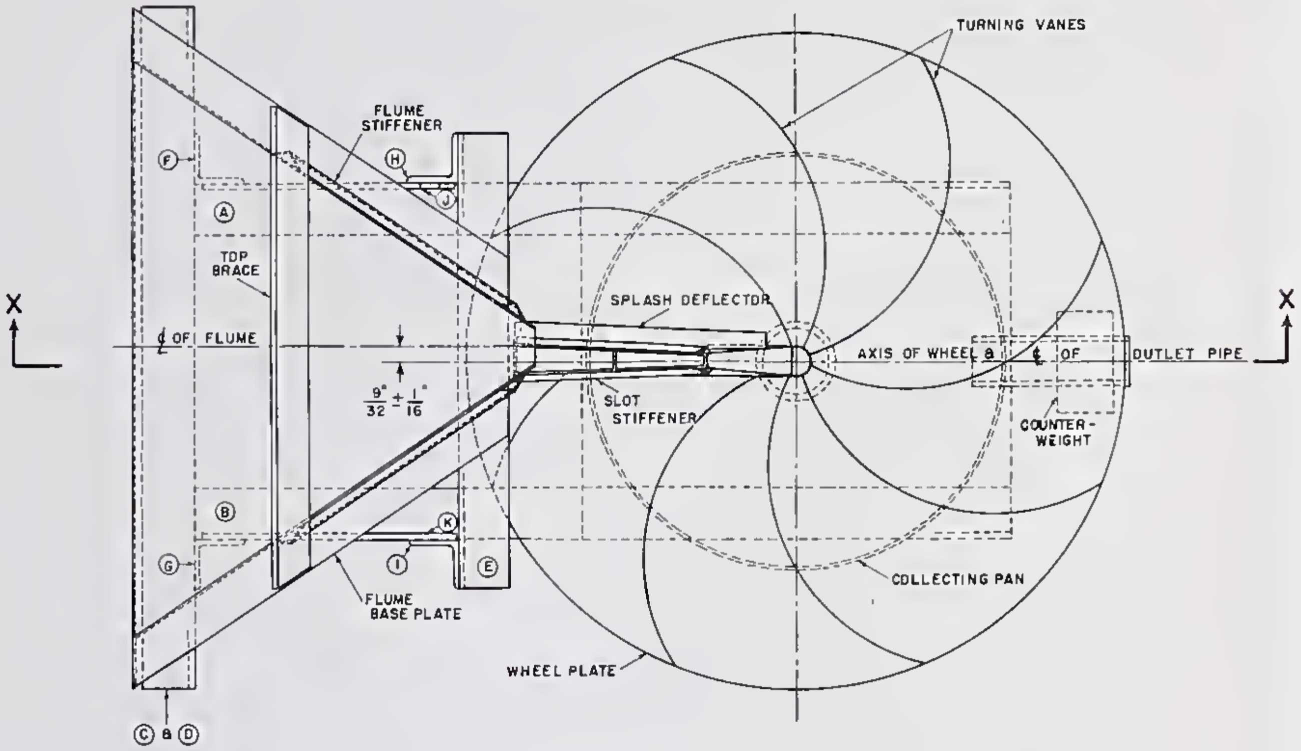


Figure 11. --Device for alinement of H-flume and Model N-1 sampler.



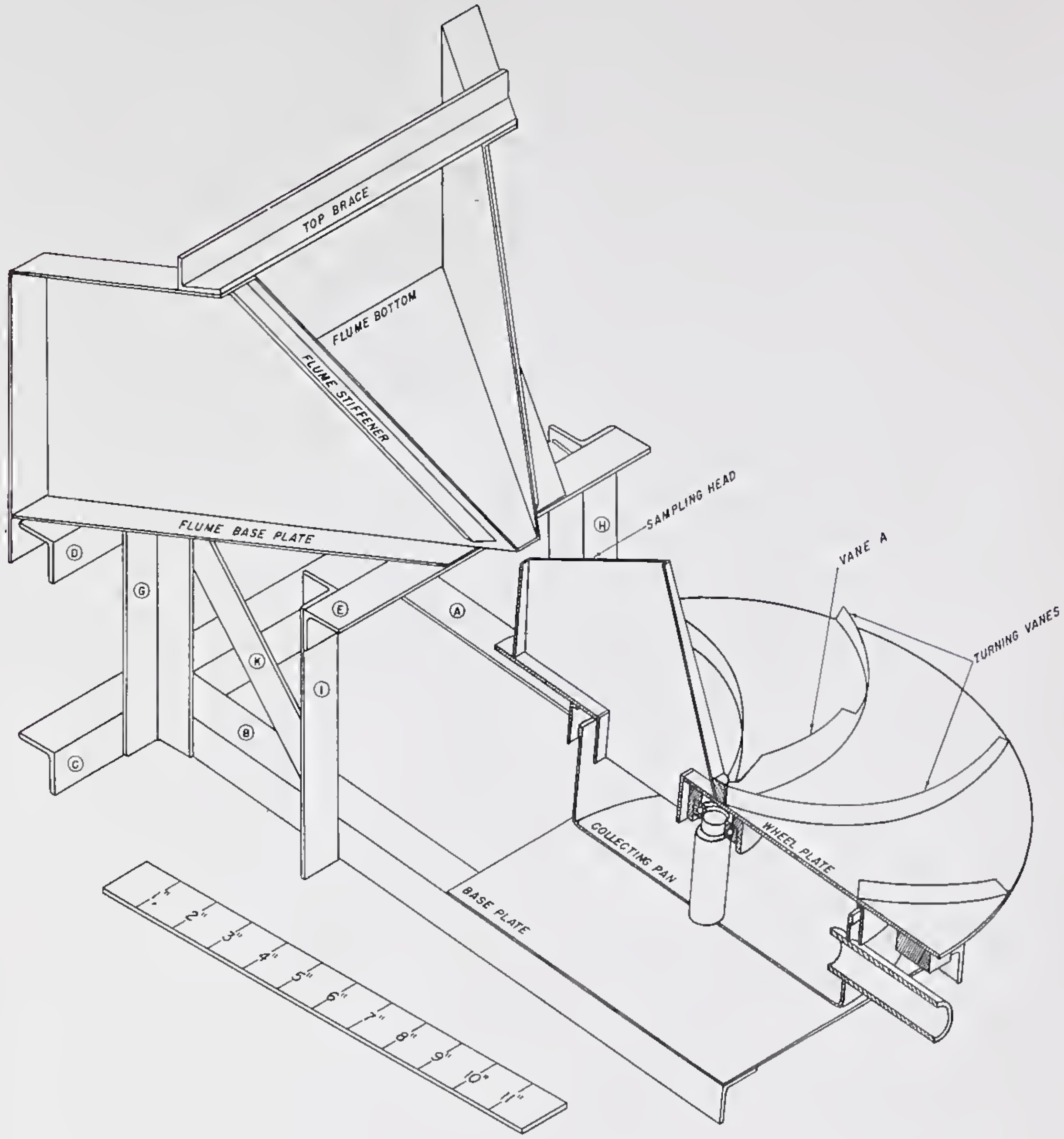
## SECTION X-X

SCALE 6"=1'-0"



## TOP VIEW

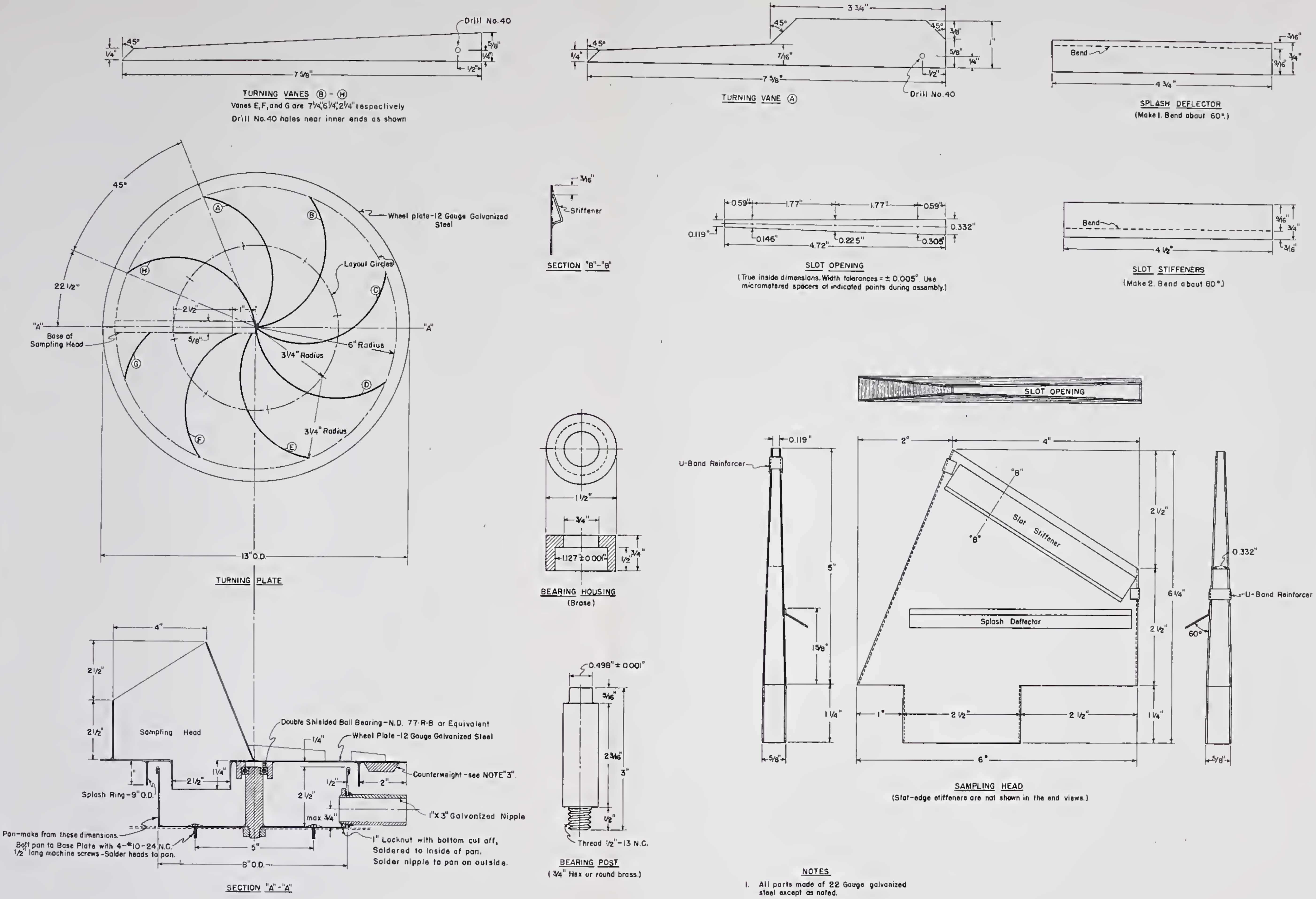
SCALE 6"=1'-0"



SEE Dwg. No. 3-P-26003 sheet 4 of 4
For Design of Support

COOPERATING AGENCIES:
MINNESOTA AGRICULTURAL EXPERIMENT STATION
SOIL CONSERVATION SERVICE
ST. ANTHONY FALLS HYDRAULIC LABORATORY

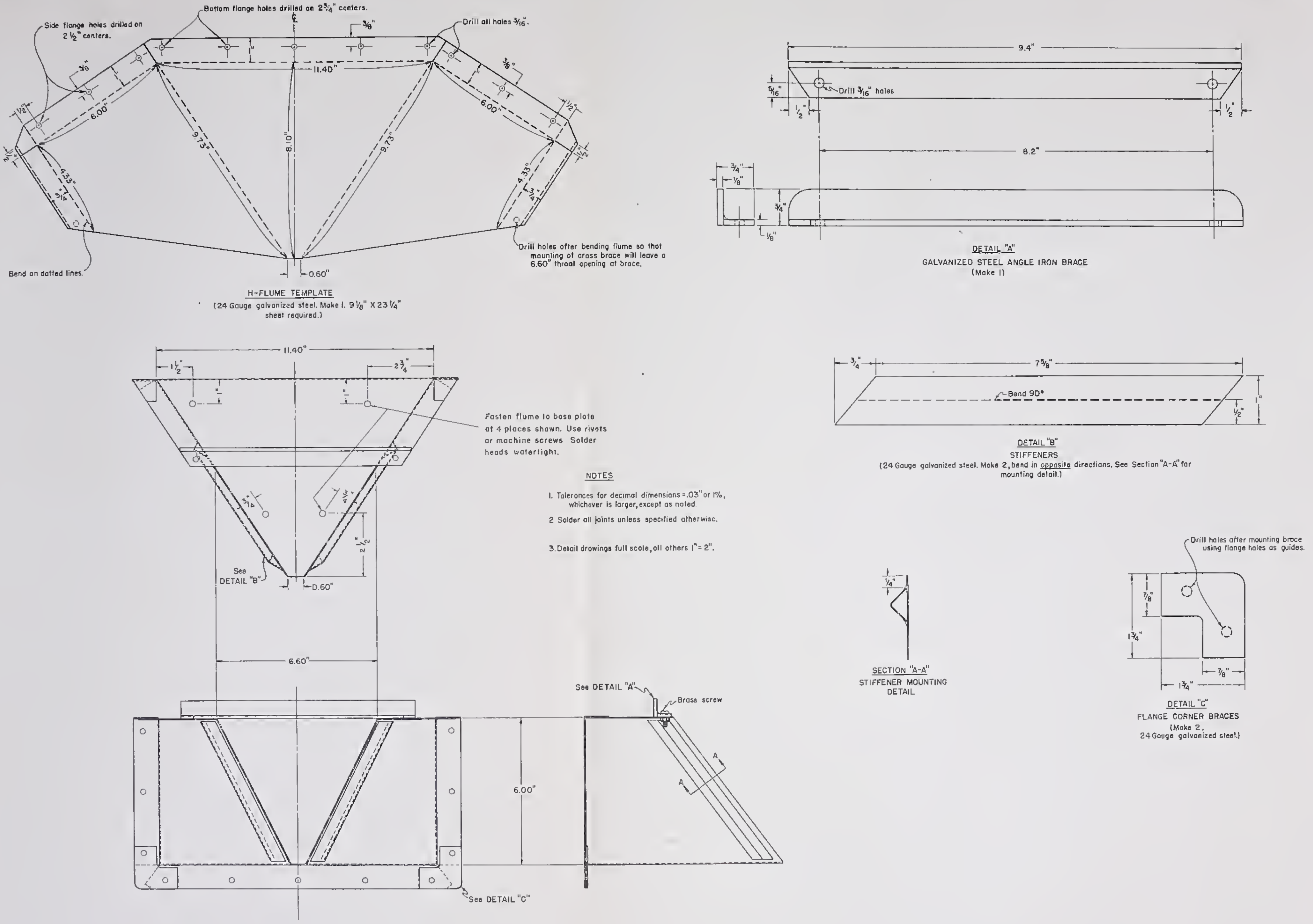
Figure 9.--Plans for Model N-1 (1-foot Coshocton-Type Runoff Sampler--general assembly).



NOTES

1. All parts made of 22 Gauge galvanized steel except as noted.
2. Soft solder all joints except as noted.
3. Increase the slope of the sampler while balancing the wheel.
4. Pan, Sampling Head, and connection between Sampling Head and Wheel are to be water-tight.

Figure 9.--Plans for Model N-1 (1-foot Coshocton-Type Runoff Sampler--construction details).



Side flange holes drilled on 2 1/2" centers.

Bottom flange holes drilled on 2 3/4" centers.

Drill all holes 3/16".

Bend on dotted lines.

Drill holes after bending flume so that mounting of cross brace will leave a 6.60" throat opening at brace.

H-FLUME TEMPLATE
(24 Gauge galvanized steel. Make 1. 9 1/8" X 23 1/4" sheet required.)

Drill 3/16" holes

DETAIL "A"
GALVANIZED STEEL ANGLE IRON BRACE
(Make 1)

DETAIL "B"
STIFFENERS
(24 Gauge galvanized steel. Make 2, bend in opposite directions. See Section "A-A" for mounting detail.)

Fasten flume to base plate at 4 places shown. Use rivets or machine screws Solder heads watertight.

NOTES

1. Tolerances for decimal dimensions ±.03" or 1%, whichever is larger, except as noted.
2 Solder all joints unless specified otherwise.
3. Detail drawings full scale, all others 1" = 2".

See DETAIL "B"

See DETAIL "A"

Brass screw

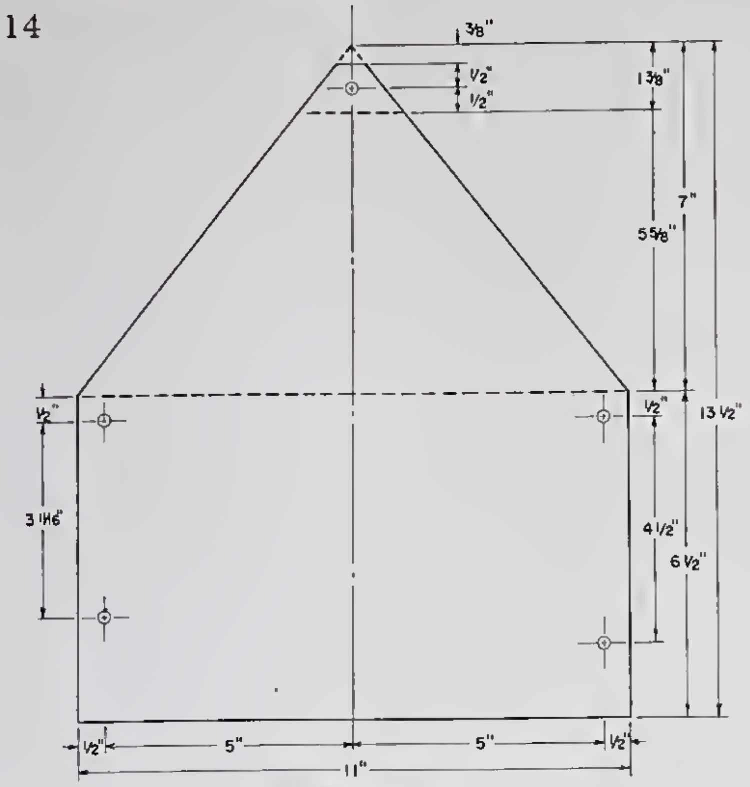
See DETAIL "C"

SECTION "A-A"
STIFFENER MOUNTING DETAIL

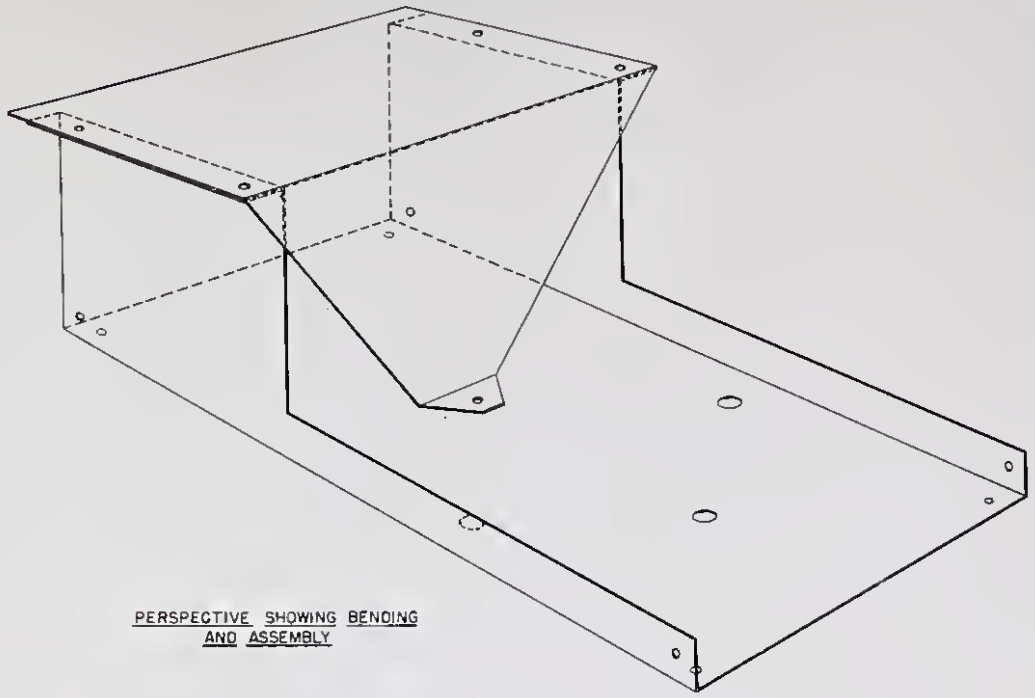
Drill holes after mounting brace using flange holes as guides.

DETAIL "C"
FLANGE CORNER BRACES
(Make 2.
24 Gauge galvanized steel.)

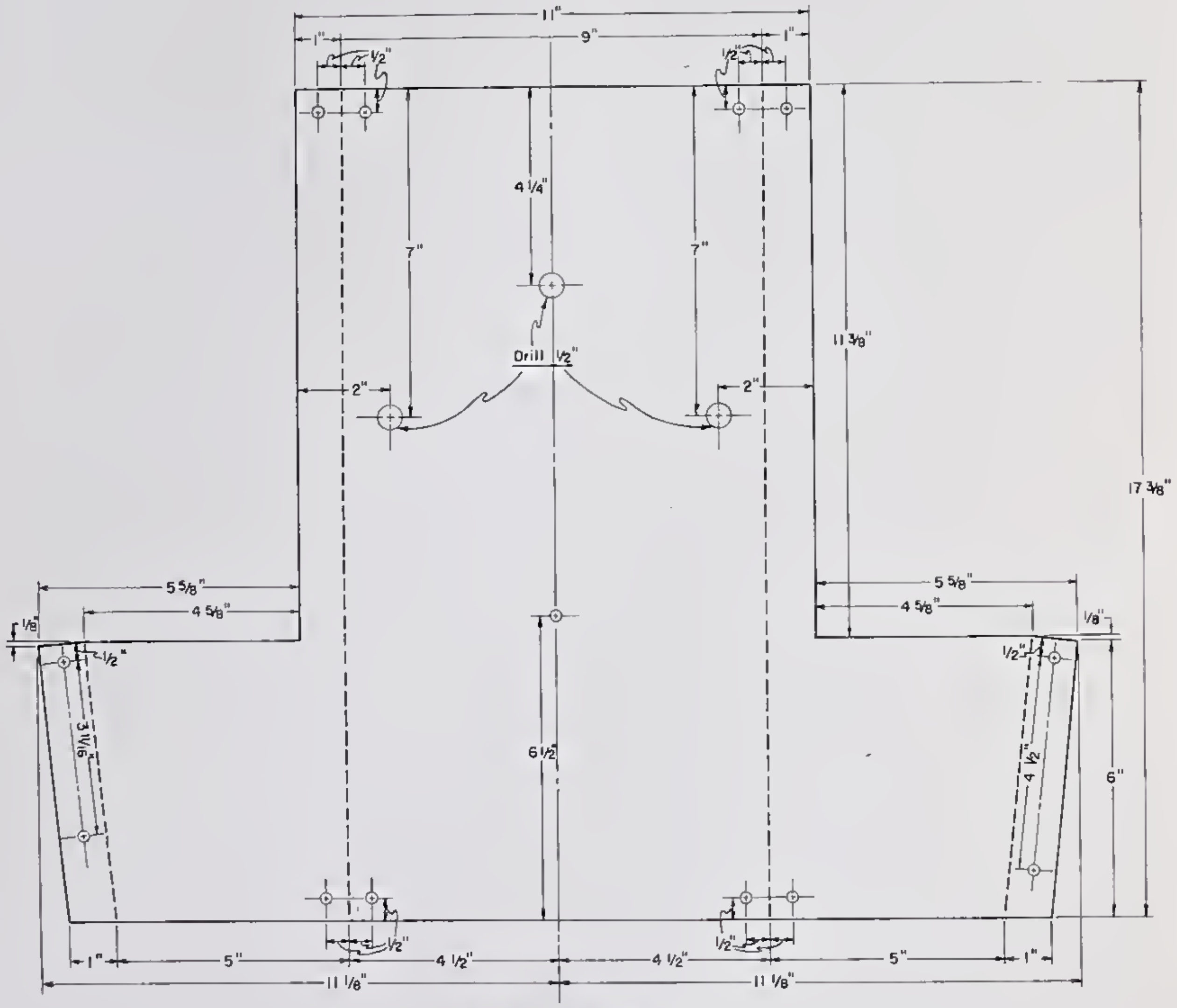
Figure 9. --Plans for Model N-1 (6-inch H-flume for Coshocton-Type Runoff Sampler).



BASE PLATE
FOR 6-IN. FLUME
(18 Gauge galvanized steel. Make 1. Bend on dotted lines.)
All holes 1/4".



PERSPECTIVE SHOWING BENDING
AND ASSEMBLY



SUPPORT FOR SAMPLER
AND BASE PLATE
(18 Gauge galvanized steel. Make 1. Bend on dotted lines.)
All holes 1/4" except as shown.

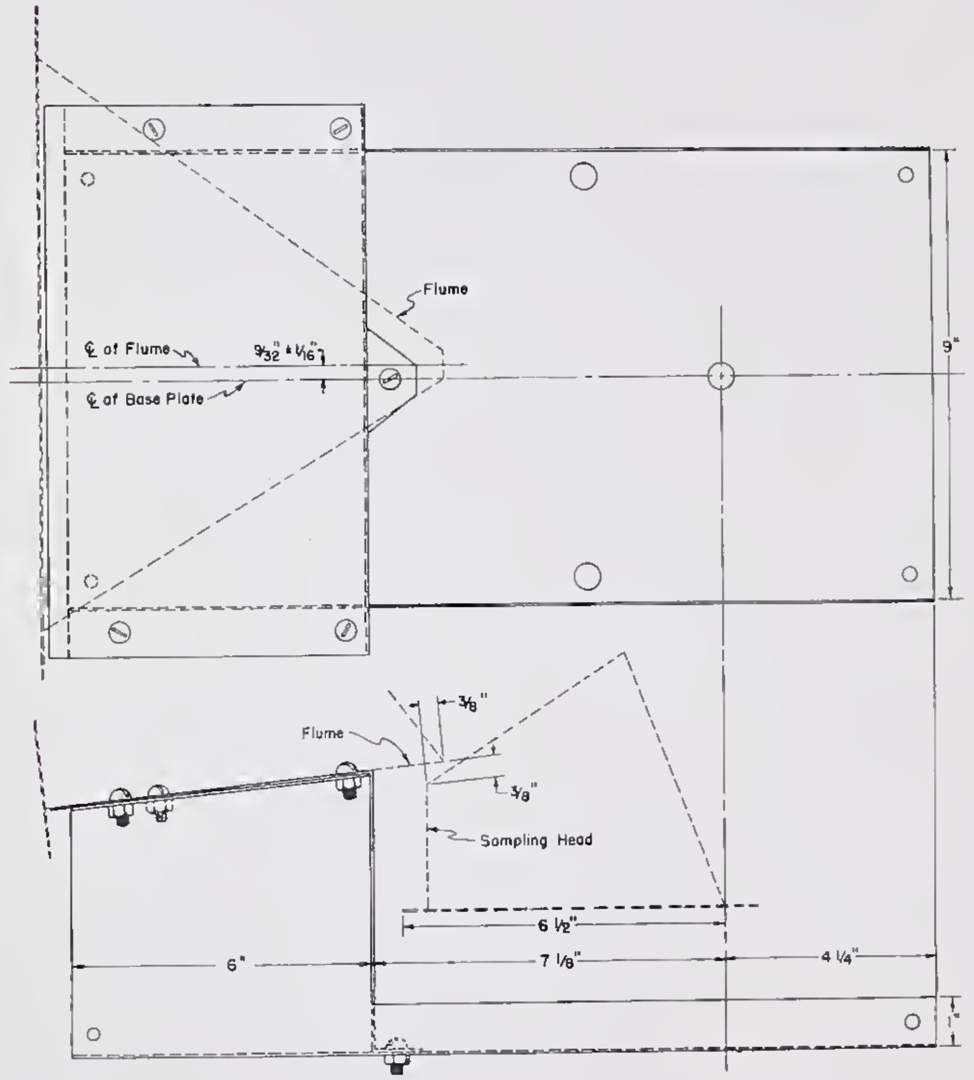


Figure 9.--Plans for Model N-1 (support for 1-foot diameter Coshocton-Type Runoff Sampler--alternate design "B").

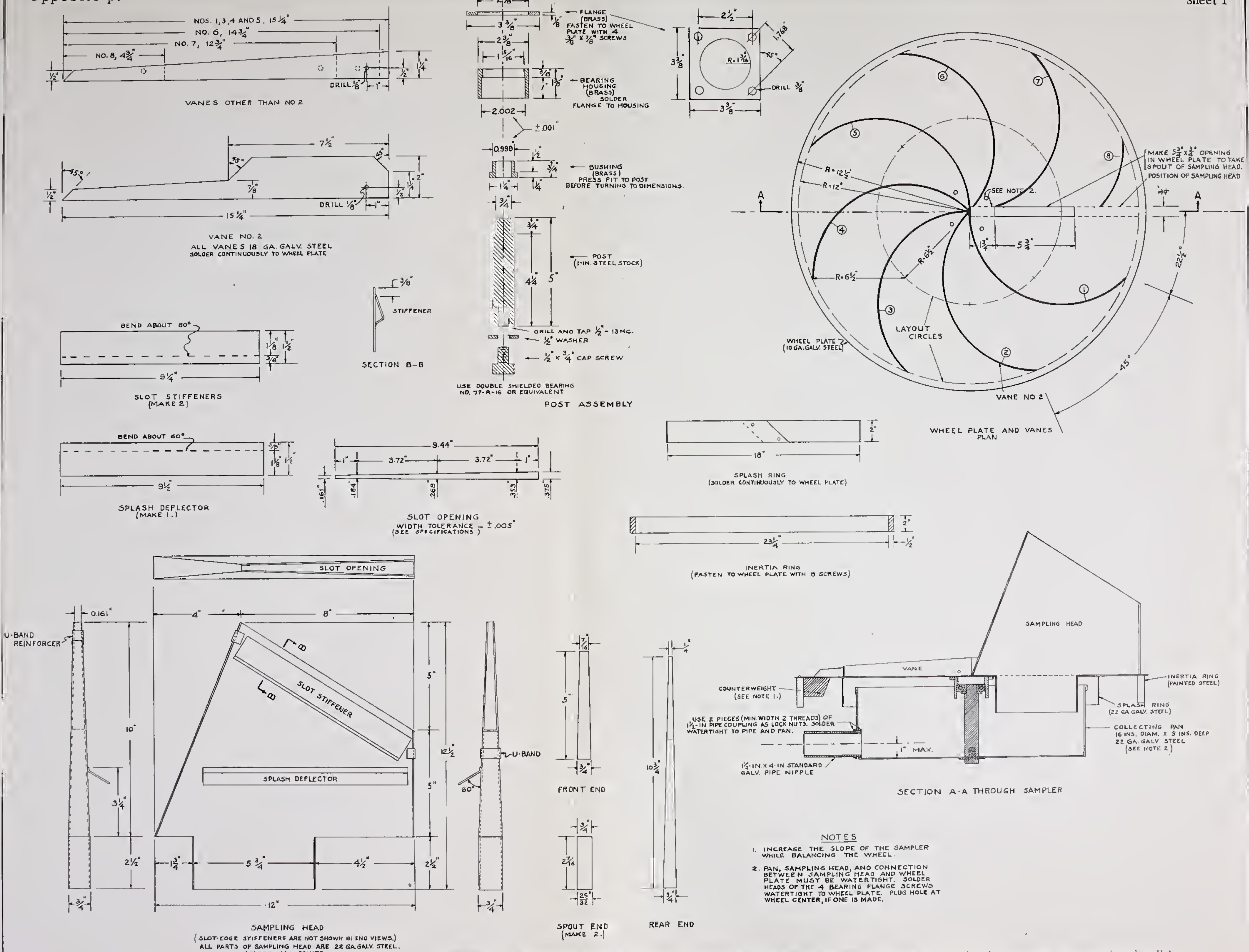

NOS. 1,3,4 AND 5, 15 1/4"
NO. 6, 14 3/4"
NO. 7, 12 3/4"
NO. 8, 4 3/4"
DRILL 1/8"
VANES OTHER THAN NO 2
7 1/2"
45°
DRILL 1/8"
15 1/4"
VANE NO. 2
ALL VANES 18 GA. GALV. STEEL
SOLDER CONTINUOUSLY TO WHEEL PLATE
BEND ABOUT 80°
9 1/4"
SLOT STIFFENERS
(MAKE 2.)
STIFFENER
SECTION B-B
BEND ABOUT 60°
9 1/2"
SPLASH DEFLECTOR
(MAKE 1.)
9.44"
3.72"
.161"
.184"
.268"
.353"
.375"
SLOT OPENING
WIDTH TOLERANCE = ±.005"
(SEE SPECIFICATIONS)
FLANGE (BRASS) FASTEN TO WHEEL PLATE WITH 4 3/8" X 7/8" SCREWS
BEARING HOUSING (BRASS) SOLDER FLANGE TO HOUSING
2.002
±.001"
0.998
BUSHING (BRASS) PRESS FIT TO POST BEFORE TURNING TO DIMENSIONS.
POST (1-IN. STEEL STOCK)
DRILL AND TAP 1/2" - 13NC.
1/2" WASHER
1/2" x 3/4" CAP SCREW
USE DOUBLE SHIELDED BEARING NO. 77-R-16 OR EQUIVALENT
POST ASSEMBLY
1.768"
R=1 3/16"
DRILL 3/8"
MAKE 5 3/4" x 3/4" OPENING IN WHEEL PLATE TO TAKE SPOUT OF SAMPLING HEAD.
POSITION OF SAMPLING HEAD
SEE NOTE 2.
R=12 1/2"
R=12"
R=6 1/2"
A
LAYOUT CIRCLES
WHEEL PLATE (16 GA. GALV. STEEL)
VANE NO 2
22 1/2°
45°
WHEEL PLATE AND VANES PLAN
18"
SPLASH RING
(SOLDER CONTINUOUSLY TO WHEEL PLATE)
23 1/4"
INERTIA RING
(FASTEN TO WHEEL PLATE WITH 8 SCREWS)
SLOT OPENING
0.161"
U-BAND REINFORCER
SLOT STIFFENER
SPLASH DEFLECTOR
U-BAND
60°
12 1/2"
SAMPLING HEAD
(SLOT-EDGE STIFFENERS ARE NOT SHOWN IN END VIEWS.)
ALL PARTS OF SAMPLING HEAD ARE 22 GA.GALV. STEEL.
SOLDER ALL JOINTS.
FRONT END
SPOUT END
(MAKE 2.)
REAR END
VANE
COUNTERWEIGHT
(SEE NOTE 1.)
INERTIA RING
(PAINTED STEEL)
SPLASH RING
(22 GA GALV. STEEL)
USE 2 PIECES (MIN. WIDTH 2 THREADS) OF 1 1/2-IN PIPE COUPLING AS LOCK NUTS. SOLDER WATERTIGHT TO PIPE AND PAN.
1" MAX.
COLLECTING PAN
16 INS. DIAM. X 5 INS. DEEP
22 GA. GALV. STEEL
(SEE NOTE 2.)
1 1/2-IN. X 4-IN. STANDARD GALV. PIPE NIPPLE
SECTION A-A THROUGH SAMPLER
NOTES
1. INCREASE THE SLOPE OF THE SAMPLER WHILE BALANCING THE WHEEL.
2. PAN, SAMPLING HEAD, AND CONNECTION BETWEEN SAMPLING HEAD AND WHEEL PLATE MUST BE WATERTIGHT. SOLDER HEADS OF THE 4 BEARING FLANGE SCREWS WATERTIGHT TO WHEEL PLATE. PLUG HOLE AT WHEEL CENTER, IF ONE IS MADE.

Figure 10. --Plans for Model N-2 (2-foot Coshocton-Type Runoff Sampler, Model N-2, 1/2 of 1 percent, construction details).

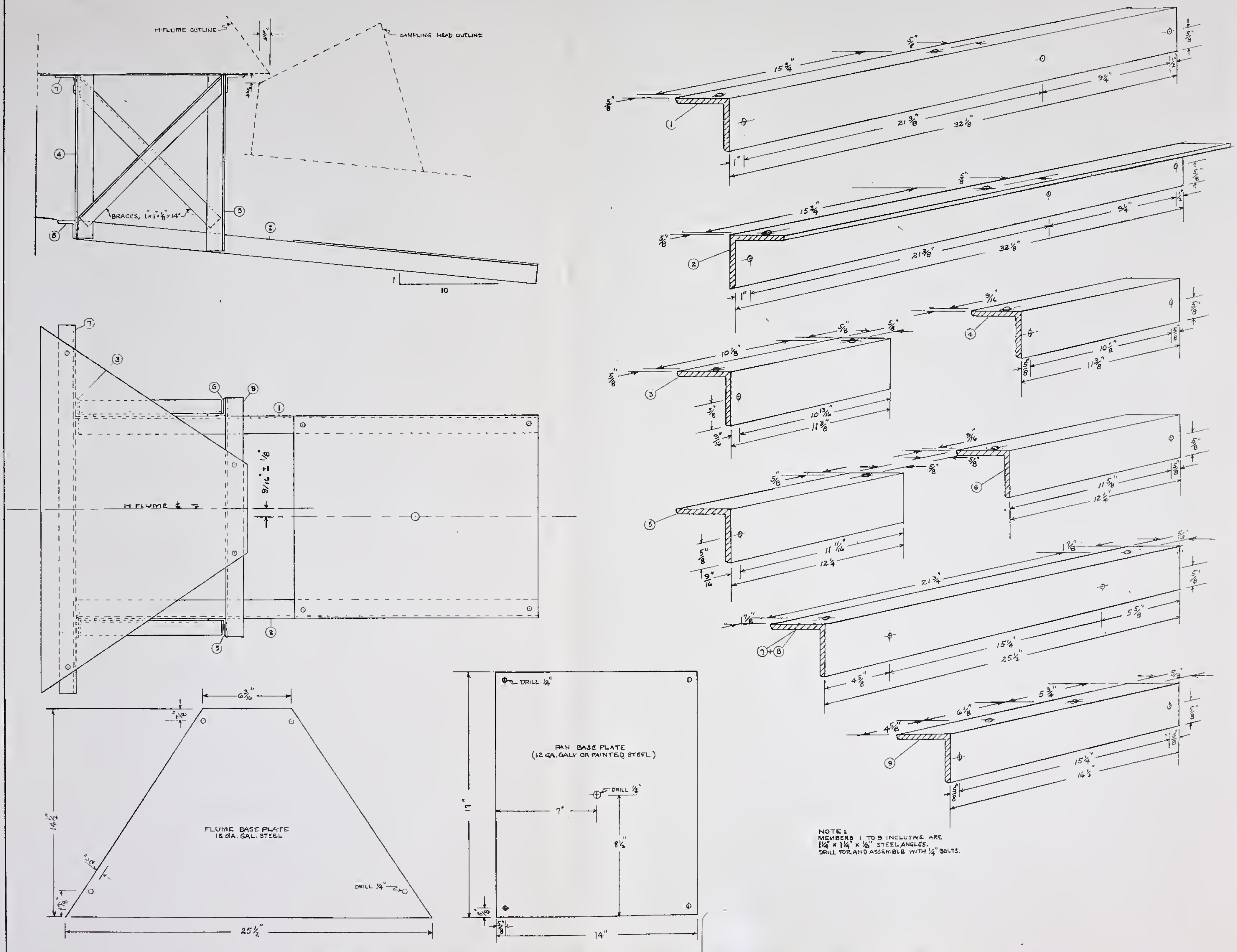
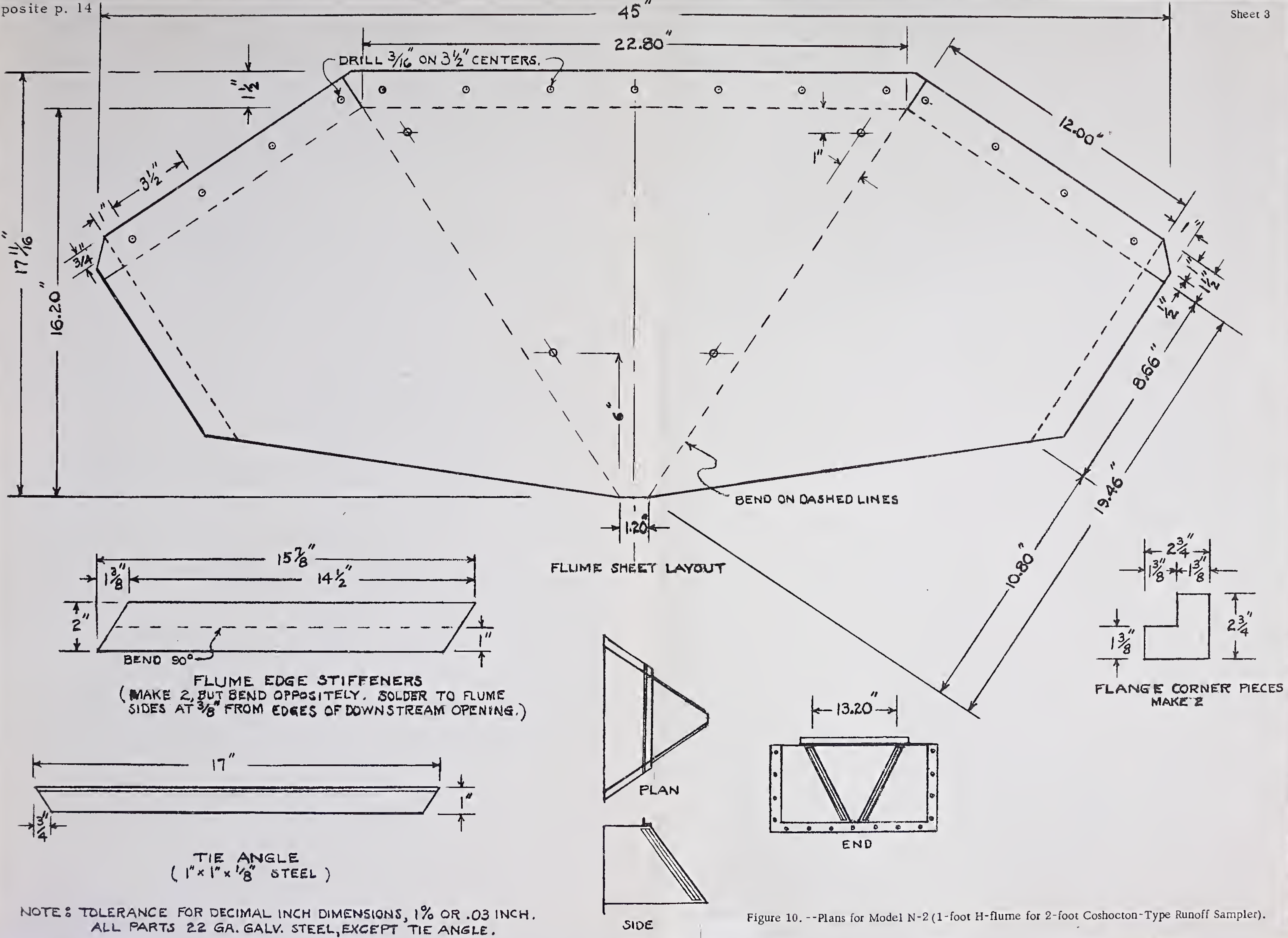


Figure 10.--Plans for Model N-2 (2-foot Coshocton-Type Runoff Sampler--support for sampler and H-flume).



NOTE: TOLERANCE FOR DECIMAL INCH DIMENSIONS, 1% OR .03 INCH.
ALL PARTS 22 GA. GALV. STEEL, EXCEPT TIE ANGLE.

Figure 10.--Plans for Model N-2 (1-foot H-flume for 2-foot Coshocton-Type Runoff Sampler).

TABLE 2.--Size schedule for sampling units

| Sampler diameter | Capacity | Headroom requirement | Aliquot | Estimated shipping | Weights net | Estimated cost (1952) |
|---|---|---|---|---|---|---|
| *Feet* | *C. f. s.* | *Feet* | *Percent* | *Pounds* | *Pounds* | *Dollars* |
| 1 | 1/3 | 1-1/4 | 1 | 26 | 18 | 60 |
| 2 | 2 | 2-1/2 | 1/2 | 130 | 85 | 115 |
| 3[1] | 5-1/2 | 3-3/4 | 1/3 | 430 | 270 | 175 |

[1] Construction details not yet available.

TABLE 3.--Minimum specifications for closed-conduit approach to sampler unit

| $D/H$ | Minimum slope | | | Minimum $y/D$ | Minimum $L_1/H$ |
|---|---|---|---|---|---|
| | $H = 0.5$ | $H = 1.0$ | $H = 1.5$ | | |
| 3/4 | 0.011 | 0.008 | 0.007 | 0.33 | 8.0 |
| 2/3 | .020 | .016 | .014 | 1.2 | 8.5 |
| 1/2 | .091 | .072 | .063 | 5.8 | 10.0 |

tank in cubic feet is then equal to 6 x 3630 x $A$ x $k$; where $A$ is the plot area in acres and $k$ is the proportion of the flow extracted by the sampler.

## Installing the Apparatus

The manner of installation of the equipment may differ somewhat depending upon conditions downhill from the experimental area. Two sketches are given in figure 12 which show possible installations and limiting distances and slopes. These apply to the use of a rectangular approach channel to the H-flume with width equal to the H-flume width.

The short section of channel immediately adjacent to the H-flume in sketch (b) has only sufficient slope for good drainage. It is provided to make room for the hydraulic jump that will occur in most installations of that type.

Other limitations are required in the event that a circular closed conduit is used between the collecting trough and the sampler unit. These are shown in table 3. The length of the horizontal transition between the lower end of the conduit and the H-flume is designated $L_1$.

The minimum vertical distance between the top of the upper end of the pipe and the maximum water elevation in the collecting trough is designated $y$. The pipe diameter $D$ and the length $L_1$ are expressed in terms of H-flume depth. The distance $y$ is expressed in terms of pipe diameter. These $y$ distances are based upon an abrupt connection of the pipe with the collecting trough. They may be reduced by 50 percent by use of a convergent-closed transition between the collecting trough and the pipe. All calculations are based upon capacity flow.

The short section of the approach channel immediately adjacent to the H-flume should have only enough slope for good drainage. The H-flume of the sampler unit should be leveled in both directions as well as can be done. The top of the H-flume should not be higher than the sill of the plot, in order to avoid flooding of the plot at maximum flow.

The closed conduit between the sampler and the storage tank should not be smaller than the outlet pipe from the sampler-collecting pan and should have no sharp-cornered or short-radius bends. It should be sloped to give good, continuous drainage and to provide the necessary head to cause flow.

The storage tank must be anchored in cases where either surface water or high ground water will provide a buoyant force. The possibility of collapse of the tank under these conditions should also be considered. The need for absolute watertightness of the sampler, sample conduit, storage tank, and connections between them cannot be overemphasized. Rain and the splash from the sampler wheel must positively be prevented from getting into the tank.

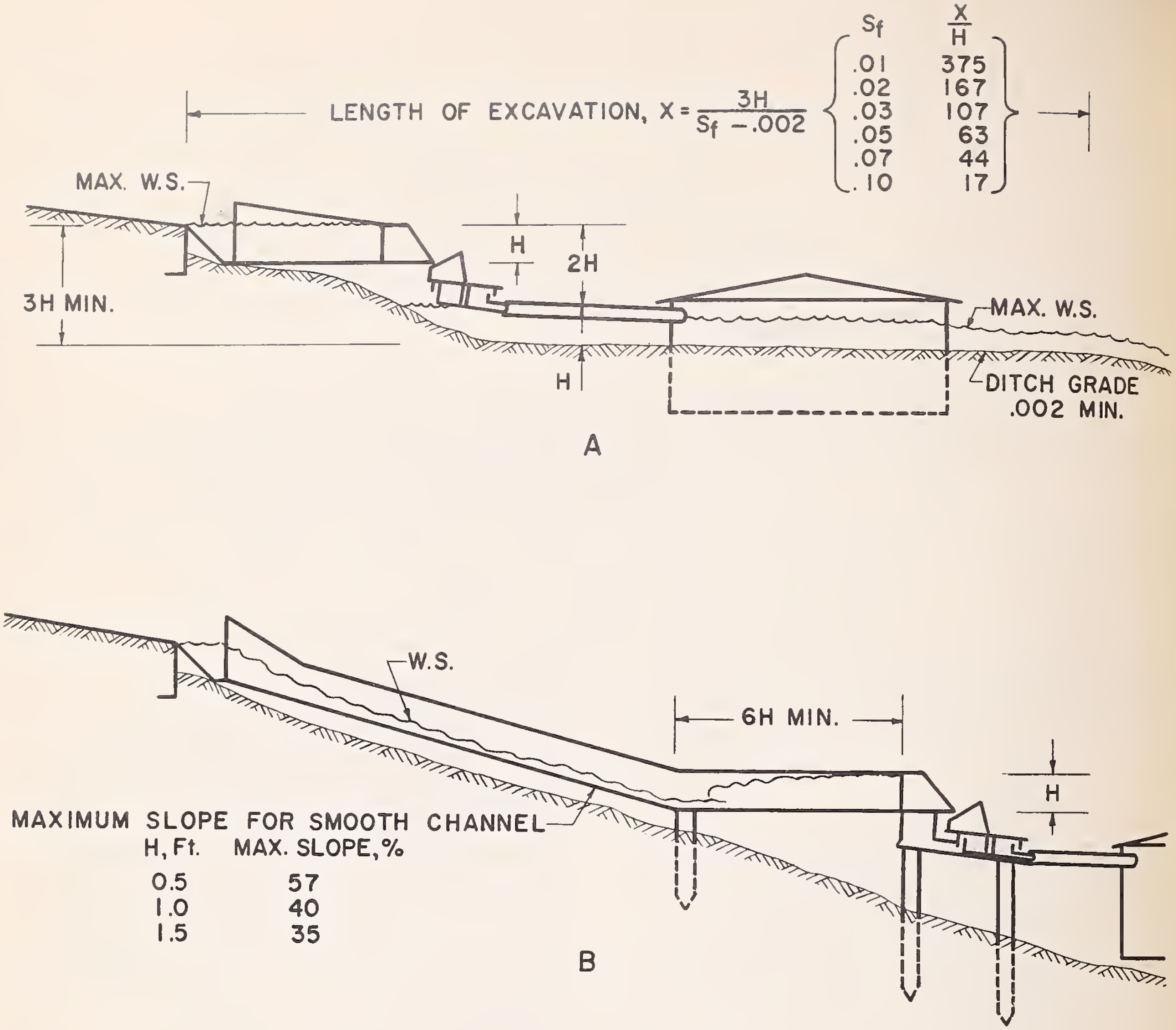


Figure 12. --Installation sketch.

July 1955 ARS-41-2

# COSHOCTON-TYPE
# RUNOFF SAMPLERS

Agricultural Research Service

UNITED STATES DEPARTMENT OF AGRICULTURE

Agriculture - Washington

# COSHOCTON-TYPE RUNOFF SAMPLERS

- - - - - -

## Supplementary Laboratory Investigations at the Stillwater, Okla., Outdoor Hydraulic Laboratory

by
Donald A. Parsons
Soil and Water Conservation Research Branch

Following completion of the work on the Coshocton sampler at the St. Anthony Falls Hydraulic Laboratory of the University of Minnesota, a number of the 1-ft samplers of a type described in SCS - TP - 124 were installed at experiment stations [1] for observation. They were generally placed in series with Geib [2] multislot devisors or other similar installations to provide a check on the soil loss and runoff measurements. The results of these field trials during 1952 and 1953 were unexplainably erratic. Also, great difficulty was experienced in the Southeast with deposition of sand in the approach trough and H-flume upstream from the sampler.

These experiences prompted a cooperative effort by the Watershed Hydrology Section and the Eastern Soil and Water Management Section of the Soil and Water Conservation Research Branch to determine and correct, if possible, the causes for the relatively poor showing of the devices in the field. This work was done at the Stillwater, Okla., Outdoor Hydraulic Laboratory [3], during the period April 22 to June 4, 1954.

[1] The following men participated in the trials:

George N. Sparrow, Tifton, Georgia
A. P. Barnett, Watkinsville, Georgia
John R. Carreker, Watkinsville, Ga.
Orville E. Hays, LaCrosse, Wisconsin
L. A. Forrest, Raleigh, N. C.
F. W. Schaller, Ames, Iowa.
H. E. Middleton, Beltsville, Md.
T. W. Edminster, Beltsville, Md.

[2] Mention of manufacturers does not constitute endorsement of their products by the U. S. Department of Agriculture.

[3] W. O. Ree and his entire staff at the laboratory were most helpful. Their consistent and skillful aid materially expedited the work.

The tests were limited to the 1-ft diameter sampler. The sampler used was constructed in the Plant Industry Station shop at Beltsville, Maryland. The essential measurements of the experimental device are shown in Figure 1 and a photograph in Figure 2.

One of the five 20-inch syphons at the Laboratory was tapped with a 6-inch line that extended into a field shelter. The water flow was controlled with a 6-inch gate valve and measured by point gage and 1-ft H-flume. The flow from the H-flume was spread across the upper end of a sloping surface that was 6 feet wide and 6 feet long. The surface was galvanized sheet steel, firmly supported by wooden flooring and timbers. Its purpose was to simulate an experimental erosion plot. A collecting trough at the foot of the sloping surface concentrated the water (runoff) at the plot centerline in a manner similar to the usual method in making soil loss and water runoff measurements.

Sand was used for the erodible material since the field trials showed that the greatest difficulties were found with installations on sandy soils. The sand was spread manually across the upper portion of the sloping surface during a test. The water then transported the material to the collecting trough. The size distribution of the sand is shown in Table 1.

TABLE 1 - The Size Distribution of the Sand

| Size | Percent |
|---|---|
| Gravel | 3 |
| Coarse Sand | 6 |
| Medium Sand | 44 |
| Fine Sand | 40 |
| Very fine sand | 4 |
| Silt and clay | 3 |

## BEARING FRICTION STUDIES

A measure of bearing friction in the experimental sampler was sought. Also desired was a method of measurement for ready field determination of friction. The bearing friction data that were obtained are given in Figure 3. The total time lapses for several numbers of revolutions of the decelerating wheel, following an initial impulse, were recorded.

The fact that straight lines may be drawn to closely represent the data when plotted as in Figure 3, implies that the friction or resistance to turning is not affected by the rate of turning. The nature of the resistance is therefore like that of dry friction between two moving solids. However, experience 4/ has shown that the resistance of lubricated bearings at low speeds does not conform with the functional relationship between friction and relative velocity of the moving parts that holds for the higher speeds.

The slopes of the lines, designated S in Figure 3, are a measure of the friction torque or moment of force causing deceleration of the rotating wheel with time. Except for test No. 1 there was a progressive

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4/ "The Mechanical Properties of Fluids", Blakie & Son,Ltd., Glasgow, page - 139 (1925) decrease in torque with successive trials that happened to coincide with a progressive increase in air temperatures. This suggests the possibility that bearing oil viscosity progressively decreased with temperature and affected friction torque. This might well be given more study.

The average value of S is .0022 and the mean kinetic friction torque is:

$$F.T. = 4\pi I \bar{S}$$

$$= 4\pi\,(0.027)\;(.0022) = .00075 \text{ ft.-lbs.,}$$

where I is the moment of inertia of the wheel about its center. 5/

The starting torque of the wheel that was used appeared to be a little too great. Whereas two 1/2 inch inside diameter radial bearings were used, a trial with bearings of about 0.3 inch should be made in an effort to reduce the torque.

## SAND DEPOSITION STUDIES

The experimental work was necessarily exploratory at the beginning. After it was learned that the major difficulty was deposition in the approach to the sampler, cut and try methods were used in an endeavor to find approach trough designs that would reduce the difficulty. Many things were tried and discarded after unrecorded observations. Rather complete measurements were made only when it seemed that an acceptable design was being approached.

5/ The moment of inertia of the wheel was determined by using it as a part of a torsion pendulum. It was rigidly connected at its center to the lower end of a long, small-diameter metal rod that was fastened securely to a support at the upper end. The moment of inertia is proportional to the square of the vibration period. The pendulum was calibrated by replacing the wheel with metal disks, for which the moments of inertia were easily calculated.

TABLE 3 - Mean Values from Sampler Tests

| Approach Channel Designation | No. of Tests | Sand Deposition Upstream from Sampler lbs. | Proportion of Total Runoff Retained by Sampler | |
|---|---|---|---|---|
| | | | Water | Sand* |
| B-3** | 4 | 2.0 | .0099 | .0101 |
| C-1 | 6 | 1.9 | .0101 | .0100 |

* Proportion of sand delivered to sampler that was retained.
** Tested with near-equal flows from each end of the collecting trough. Greater deviations in sampler catch should be expected for extreme asymmetry of flow in the collecting trough.

(7) A small amount of sand deposited on the wheel plate near the end of runoff appeared to produce no serious effects on sampler operations.

(8) Tests were made to determine the horizontal clearance required for hoods that may be used to protect the sampler wheel from wind, small boys, etc. A minimum clearance of 2-inches for the 1-foot diameter wheel is necessary. A greater distance would be preferable, especially if possible trash difficulties are considered.

(9) Although care was used in handling the sampler during the tests, it is still significant that no difficulty was experienced with either sand or water in the bearing.

(10) The slope of the wheel plate in the sampler that was used for the tests was 0.186 (1 on 5.3) instead of 0.10 specified on the plans. This increases the required headroom for operation by one inch. The beneficial effect of the increase in slope, is an increase in the turning moment of force for trickle flows.

The use of a bearing assembly with greater friction than in the original design for the purpose of reducing the wobble of the wheel makes an increase in tilt of the wheel desirable in a future design.

(11) A small amount of sand was caught in the pan in each test. The pan outlet was a street elbow attached to the bottom of the pan, that requires 2 inches headroom more than the current plans indicate. This street elbow outlet is probably much better than the one shown on the plans from the standpoint of catching sand, but neither of them is good. A new design should be developed that will pass sand better without an increase in headroom requirement. (Two inches extra headroom, for example, requires 5 feet of extra digging at the deep end of the trench for a plot on a 3% slope).

(12) Experience with heavy sand loads in the runoff suggests that adequate slope of the conduit between the sampler and the sample tank must be provided. Minimum slope requirement was not determined. For this condition a minimum slope of five percent is suggested on a trial basis.

(13) A few tests with trash, (bermuda grass, both dead and green) demonstrated that the wheel could be stopped by the trash wedging between the wheel and the downstream portion of the H-flume support. This support should be redesigned to provide greater clearance for the wheel.

(14) The H-flume approach to the sampler should not be depended upon as a flow measuring device when preceded by approach B-3 or C-1.

TABLE 2

TEST DATA - STILLWATER, OKLAHOMA TESTS OF COSHOCTON-TYPE RUNOFF SAMPLER, N-1

| TEST NO. | DATE (1954) | APPROACH DESIGNATION | FLOW, Q | SAND TO PLOT | SAND CONCENTRATION OF PLOT RUNOFF | SAND IN APPROACH CHANNEL | SAND PASSING SAMPLER H-FLUME, S | WATER SAMPLE | TEST TIME | SAMPLER FLOW, q | WATER RATIO R is q/Q | SAND(1) SAMPLE, s | SAND RATIO (1) Rs is s/S | WHEEL SPEED | APPROACH VELOCITY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | cfs. | lbs. | pct. by wt. | lbs. | lbs. | lbs. | sec. | cfs. | | lbs. | | rpm. | ft/sec |
| 1 | 5-11 | A-1 | 0.201 | 59.7 | 1.0 | 45.9 | 13.8 | 64.57 | 472.8 | .00219 | .01092 | 0.146 | .0105 | | |
| 2 | 5-13 | A-1 | 0.201 | 99.0 | 1.9 | 58.5 | 40.5 | 54.11 | 420.2 | .002067 | .01028 | 0.328 | .0081 | | |
| 3 | 5-14 | A-1 | 0.201 | 32.7 | 0.6 | 23.5 | 9.2 | 56.95 | 437.6 | .00209 | .01030 | 0.084 | .0091 | | |
| 4 | 5-14 | A-1 | 0.1026 | 33.6 | 1.1 | 29.6 | 4.0 | 30.61 | 475.4 | .001024 | .00998 | 0.035 | .0088 | | |
| 5 | 5-14 | A-1 | 0.1018 | 65.2 | 2.4 | 53.9 | 11.3 | 32.40 | 479.6 | .001085 | .01065 | 0.100 | .0088 | | |
| 6 | 5/15 | A-1 | 0.300 | 64.3 | 1.4 | 39.7 | 24.6 | 47.10 | 252.2 | .003000 | .01000 | 0.231 | .0094 | | |
| 7 | 5-16 | A-2 | 0.205 | 64.3 | 1.2 | 12.0 | 52.3 | 54.36 | 411.6 | .002120 | .01035 | 0.480 | .0092 | | |
| 8 | 5-17 | A-2 | 0.0986 | 67.4 | 2.3 | 21.8 | 45.6 | 28.32 | --- | --- | --- | 0.457 | .0100 | | |
| 9 | 5-17 | A-2 | 0.300 | 99.4 | 2.0 | 25.6 | 73.8 | 46.65 | 261.2 | .00287 | .00957 | 0.685 | .0093 | | |
| 10 | 5-18 | A-3 | 0.198 | 69.9 | 1.2 | 9.5 | 60.4 | 59.80 | 472.2 | .002032 | .01027 | 0.599 | .0099 | | |
| 11 | 5-18 | A-3 | 0.299 | 108.2 | 2.3 | 17.2 | 91.0 | 46.07 | 253.6 | .002918 | .00976 | 0.760 | .0084 | | |
| 12 | 5-20 | B-1 | 0.200 | 67.9 | 1.1 | 1.1 | 66.8 | 60.54 | 486.4 | .001997 | .00999 | 0.665 | .0100 | | |
| 13 | 5-21 | B-1 | 0.300 | 100.5 | 3.0 | 3.1 | 97.4 | 31.20 | 181.2 | .002766 | .00922 | 0.995 | .0102 | | |
| 14 | 5-21 | B-1 | 0.0994 | 35.8 | --- | 4.1 | 31.7 | 13.57 | --- | --- | --- | 0.270 | .0085 | | |
| 15 | 5-26 | B-2 | 0.1002 | --- | --- | 1.6 | --- | 28.08 | 490.2 | .000920 | .00917 | 0.549 | --- | | |
| 16 | 5-31 | C-1 | 0.194 | 37.0 | 2.2 | 5.3 | 31.7 | 18.13 | 141.6 | .002055 | .01059 | 0.315 | .00995 | 47 | 4.8 |
| 17 | 5-31 | C-1 | 0.201 | 33.0 | 1.7 | 0.9 | 32.1 | 19.07 | 153.6 | .001992 | .00991 | 0.318 | .00990 | 48 | 6.5 |
| 18 | 5-31 | C-1 | 0.0506 | 32.9 | 2.1 | 2.2 | 30.7 | 15.70 | 489.6 | .000515 | .01018 | 0.305 | .00995 | 27 | 3.9 |
| 19 | 6-1 | C-1 | 0.0501 | 34.8 | 2.2 | 0.1 | 34.7 | 16.13 | 503.5 | .000514 | .01027 | 0.360 | .01038 | 33.5 | 4.9 |
| 20 | 6-1 | C-1 | 0.0253 | 17.9 | 2.3 | 2.2 | 15.7 | 8.07 | 500 ± | .000259 | .01024 | 0.141 | .00896 | 36 | 3.6 |
| 21 | 6-1 | C-1 | 0.0257 | 17.9 | 2.2 | 0.4 | 17.5 | 7.69 | 506.5 | .000244 | .00949 | 0.161 | .00917 | 33.5 | 5.0 |
| 22 | 6-4 | B-3 | 0.197 | 70.9 | 2.4 | 1.3 | 69.6 | 28.90 | 245.6 | .001890 | .00960 | 0.647 | .00929 | | |
| 23 | 6-4 | B-3 | 0.0979 | 68.0 | 2.3 | 1.2 | 66.8 | 28.02 | 474.8 | .000948 | .00969 | 0.629 | .00941 | | |
| 24 | 6-4 | B-3 | 0.0516 | 32.8 | 2.1 | 2.9 | 29.9 | 15.38 | 476.0 | .000519 | .01006 | 0.305 | .01021 | | |
| 25 | 6-4 | B-3 | 0.0250 | 18.5 | 2.3 | 2.5 | 16.0 | 8.07 | 511.2 | .000254 | .01014 | 0.162 | .01014 | | |

The several sand moisture determinations that were required in each test to put the erodible material on a dry weight basis made the test procedure quite cumbersome. Test data are summarized in Table 2. Plans for the two approach designs, designated B-3 and C-1 and judged to be most suitable, are shown in Figures 4a, 4b and 5.

A summarization of the results of the work includes the following:

(1) A large amount of deposition occurred within the H-flume and the approach channel when a 2 foot long, level channel with width equal to the upstream end of the H-flume was used. For example, in Test No. 1, there was about 45 lbs. of sand deposited above the sampler, which would be equivalent to more than one ton per acre for a .02-acre plot.

(2) The amount of deposition generally increased with the rate of sand feed or sand concentration of the runoff.

(3) The sampler behaved in general as expected from the Minnesota tests; i.e., both the sand and water fractions retained by the sampler were reasonably correct as long as the wheel speeds were at or near those obtained in the original calibration tests.

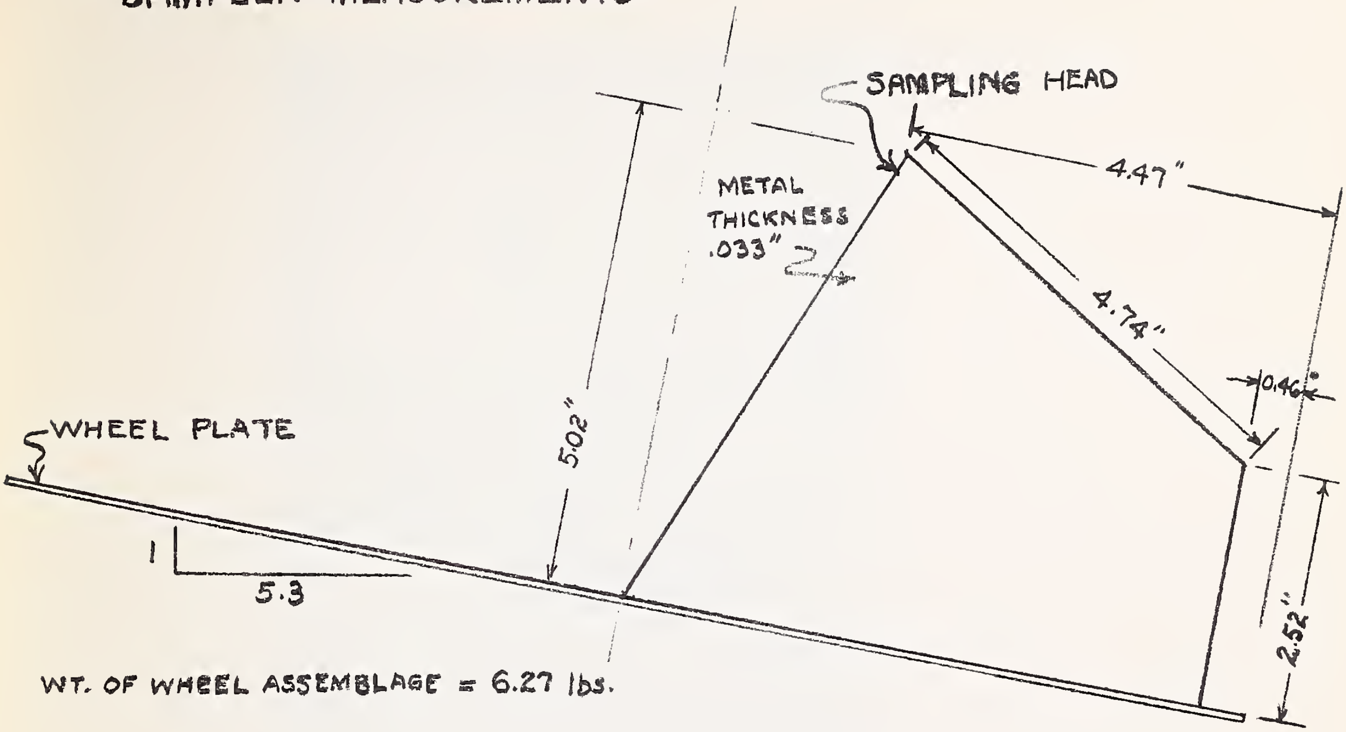
(4) The rate of turning of the wheel was sensitive to differerences in approach conditions. This was the basic reason for originally adopting the H-flume approach as an integral part of the sampler. The Oklahoma tests showed, however, that approach conditions to the H-flume that caused seemingly minor changes in the H-flume jet changed the wheel

speeds materially. Deposition in the approach channel could therefore affect wheel speeds and the catch of the sampler by alteration of the H-flume jet. As an illustration of the effect of wheel speed on the sampler catch, an unrecorded measurement of the water sample, obtained at a wheel speed double the normal rate of turning, showed the sample to be 18% low.

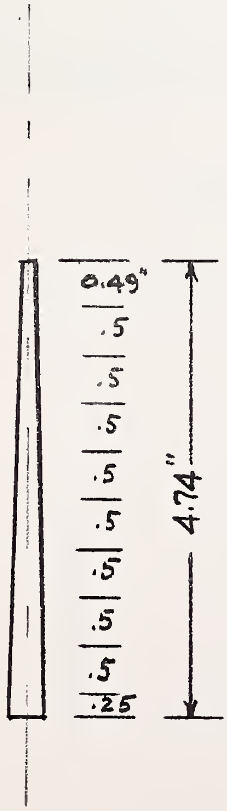
(5) Whereas the Minnesota tests showed that the proportion of coarse sand retained by the sampler increased materially with flow rate, the medium to very fine sand used in the Oklahoma tests was retained by the sampler more nearly as the water was retained.

(6) Since the preliminary exploratory tests demonstrated that the major difficulty in the use of the equipment was upstream sedimentation, the later work was concentrated upon development of approach channel designs that would reduce this difficulty. Although a large number of new designs were tried, only four of them were seriously considered as being adequate, and only two of these were accepted as the end products. One design, approach C-1, is for use when the runoff comes to the sampler at high velocity (5 to 9 ft./sec.) through a pipe or narrow channel, and the other, approach B-3, is for direct connection to the collecting trough at the foot of the experimental plot area. Mean values of the test results obtained at flows ranging between .025 and 0.20 cfs. are given in Table 3 for these designs.

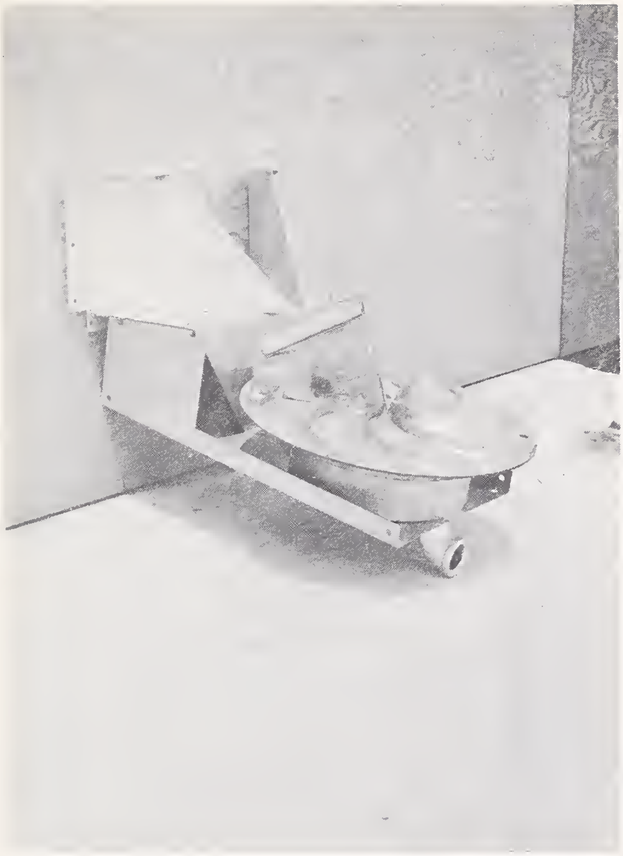
Figure 1.-
SAMPLER MEASUREMENTS



WT. OF WHEEL ASSEMBLAGE = 6.27 lbs.



| POSITION | SLOT WIDTH, INS TRIAL NO. 1 | 2 | MEAN | SPEC. | DIFF. |
|---|---|---|---|---|---|
| 1 | .150 | .150 | .150 | .142 | .008 |
| 2 | .172 | .172 | .172 | .164 | .008 |
| 3 | .193 | .192 | .193 | .187 | .007 |
| 4 | .216 | .214 | .215 | .210 | .005 |
| 5 | .232 | .232 | .232 | .232 | .000 |
| 6 | .250 | .250 | .250 | .255 | -.005 |
| 7 | .275 | .274 | .274 | .277 | -.003 |
| 8 | .297 | .297 | .297 | .300 | -.003 |
| 9 | .320 | .320 | .320 | .323 | -.003 |



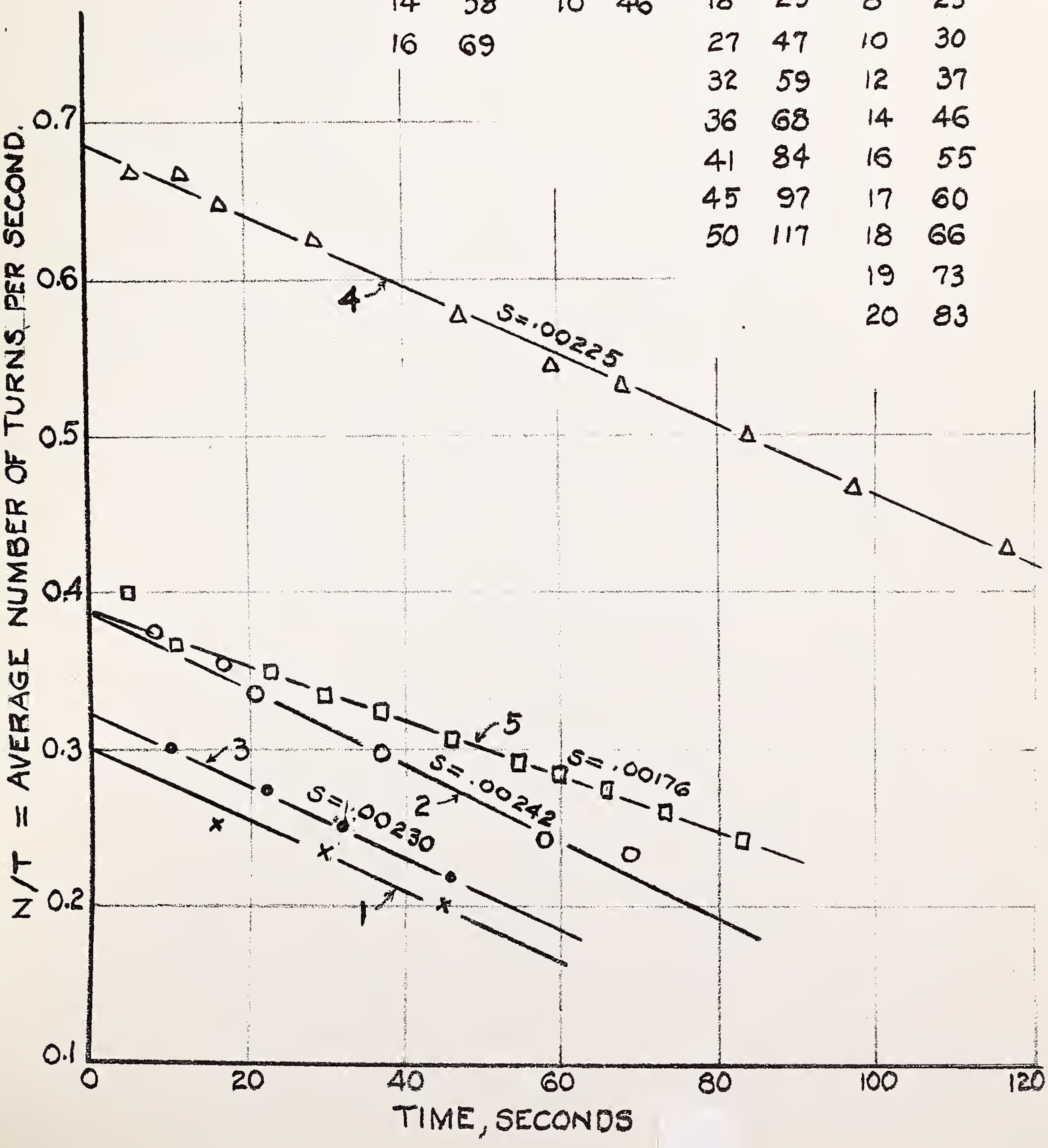
1 - ft. COSHOCTON TYPE
RUNOFF SAMPLER

Constructed in Plant Industry Station
Shop, Beltsville, Maryland

# FIGURE 3

## FRICTION TORQUE DATA

| TEST NO. | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | T | N | T | N | T | N | T | N | T |
| | 0 | 0 | | | | | | | | |
| | 4 | 16 | 3 | 8 | 3 | 10 | 4 | 6 | 2 | 5 |
| | 7 | 30 | 7 | 21 | 6 | 22 | 8 | 12 | 4 | 11 |
| | 9 | 45 | 11 | 37 | 8 | 32 | 11 | 17 | 6 | 17 |
| | | | 14 | 58 | 10 | 46 | 18 | 29 | 8 | 23 |
| | | | 16 | 69 | | | 27 | 47 | 10 | 30 |
| | | | | | | | 32 | 59 | 12 | 37 |
| | | | | | | | 36 | 68 | 14 | 46 |
| | | | | | | | 41 | 84 | 16 | 55 |
| | | | | | | | 45 | 97 | 17 | 60 |
| | | | | | | | 50 | 117 | 18 | 66 |
| | | | | | | | | | 19 | 73 |
| | | | | | | | | | 20 | 83 |



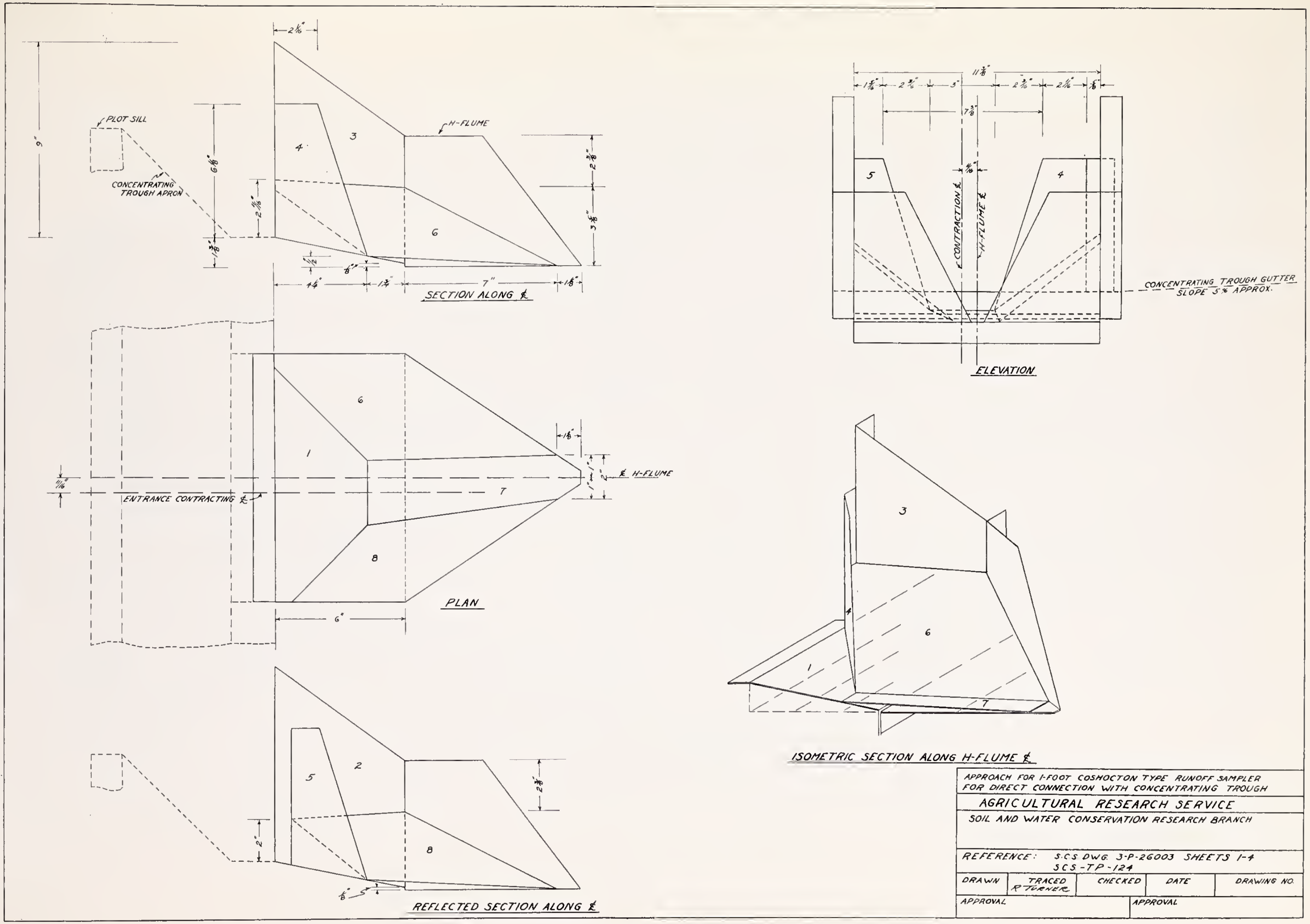

PLOT SILL
CONCENTRATING TROUGH APRON
H-FLUME
SECTION ALONG ℄
PLAN
ENTRANCE CONTRACTING ℄
℄ H-FLUME
REFLECTED SECTION ALONG ℄
ELEVATION
CONTRACTION ℄
H-FLUME ℄
CONCENTRATING TROUGH GUTTER SLOPE 3% APPROX.
ISOMETRIC SECTION ALONG H-FLUME ℄
9"
6"
7"
2"
1"
1
2
3
4
5
6
7
8
APPROACH FOR 1-FOOT COSHOCTON TYPE RUNOFF SAMPLER FOR DIRECT CONNECTION WITH CONCENTRATING TROUGH
AGRICULTURAL RESEARCH SERVICE
SOIL AND WATER CONSERVATION RESEARCH BRANCH
REFERENCE: S.C.S. DWG. 3-P-26003 SHEETS 1-4 SCS-TP-124
DRAWN
TRACED R TURNER
CHECKED
DATE
DRAWING NO.
APPROVAL
APPROVAL

Figure 4 a - Approach B-3 (sheet 1 of 2)

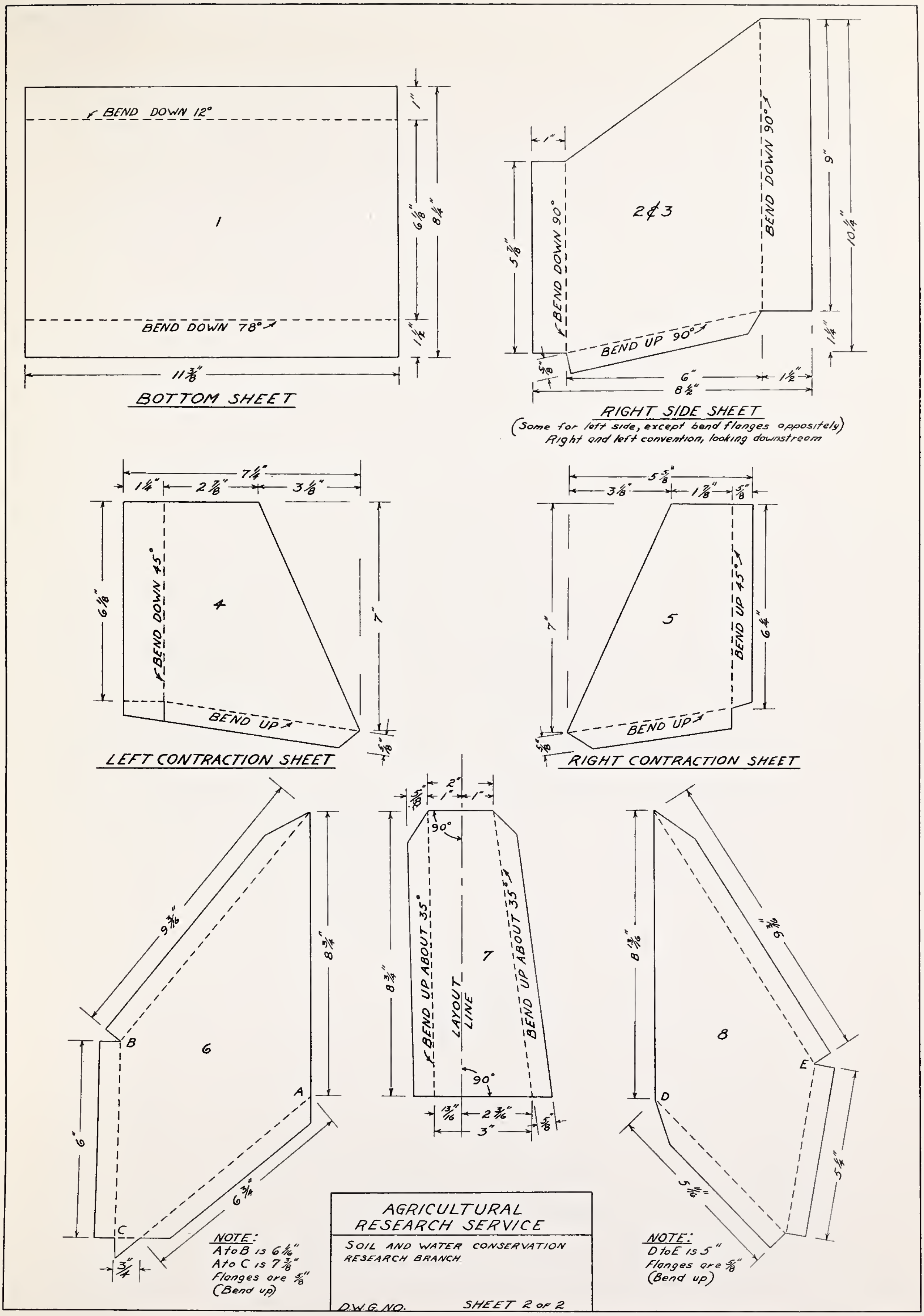


Figure 4 b - Approach B-3 (sheet 2 of 2)

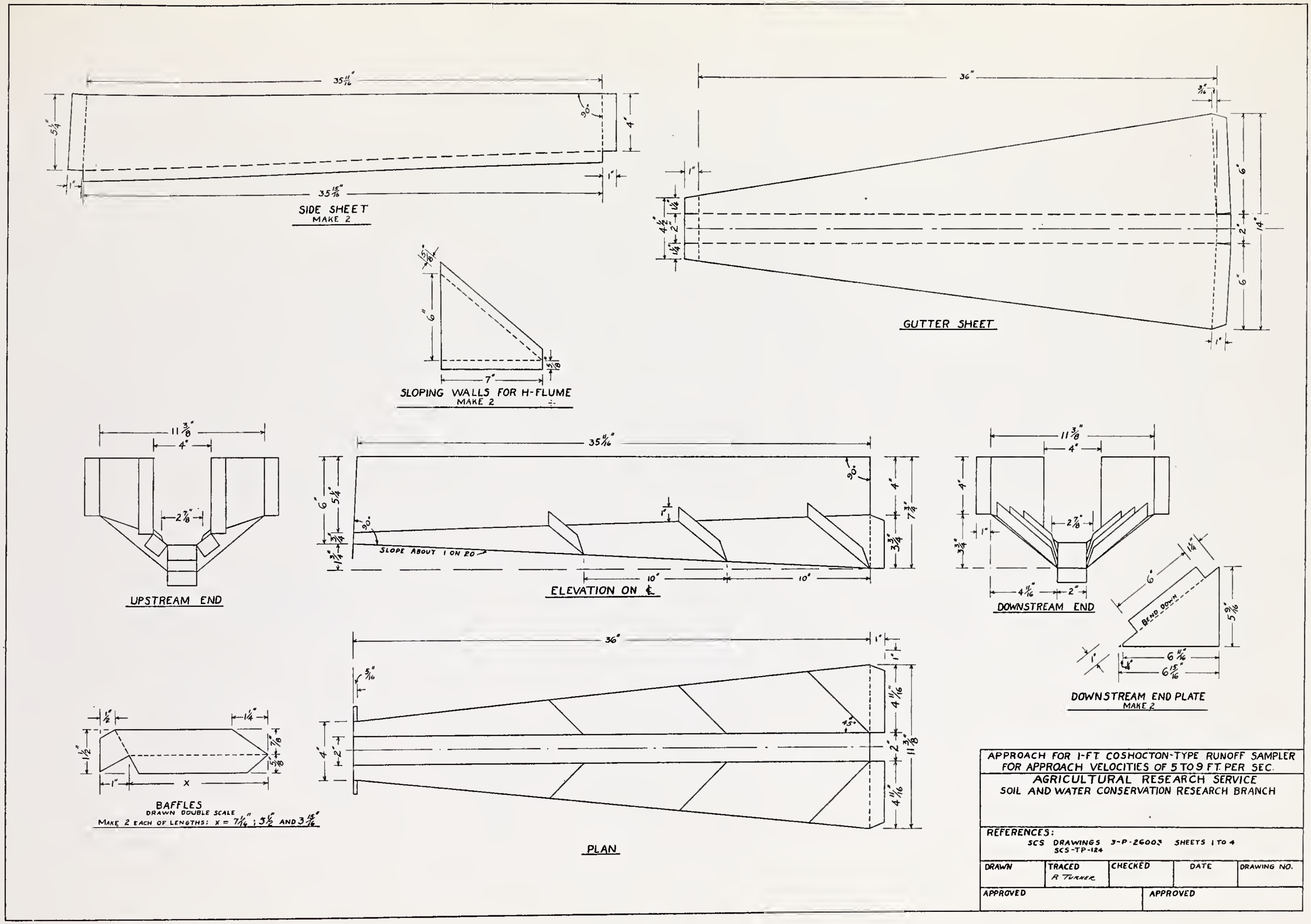


Figure 5 - Approach C - 1